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Development of WebGIS based Information System: A case study of energy sector

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Abstract: Geographical information is captured and stored in a huge amount nowadays. The attribute value of spatial information is deployed across many communities and websites. To store, manage and analyse this geospatial data, the common centralized system is required. Currently, information regarding energy sectors of India is not available on any centralized system and is unstructured. Accessing energy data is time-consuming and creates interoperability issues and provides irrelevant data as most of the available data may be redundant, non-geospatial or managed by various departments. The depleting conventional resources and increasing energy usage requires proper energy planning which requires an integrated and updated centralized system. The developed Information system collects the relevant data and manages it according to geographical information. This system is developed for better understanding and decision making by providing geographical information available along with energy statistics on a single platform. WebGIS open source technology is used for developing a centralized system to relate available information with geospatial data and disseminate information using maps and charts. Developed WebGIS based system is easy to understand and has a user-friendly interface. An Automated Module is developed to transform non-spatial energy data (with geographic coordinates) to spatial data to reduce manual processes. It is expected that the availability of information will support stakeholders and administrators for better decision making and will help users to understand and save energy.

Keywords: WebGIS, Open source, Energy, Geospatial, Information system

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1. Introduction

Energy is the key factor to develop society's economic growth and improve quality of life. It plays a vital role in evolution, survival and development of all living beings. India has enough resources, better land structure and environmental conditions i.e. adequate sunshine, balanced wind speed to produce renewable energy yet nearly 20% of the total population does not have access to electricity (Indian Wind Energy, A Brief Outlook, 2017). For substantial growth, the demand of energy is increasing day by day. As the world's most populous country, development of infrastructure and better policy planning is required to fulfil ever-growing energy demands. Development of policy planning needs long-term stability and clarity of information. Most of the energy-related information is scattered, maintained by various departments, redundant or may be unavailable. Accessing this type of data is time-consuming and creates interoperability issues and provides irrelevant data as there is no common centralized system available for information storage. There are many portals developed by various ministries for individual purposes. Ministry of New and Renewable Energy (MNRE) developed a portal (www.mnre.gov.in) for matters related to new and renewable energy production and development. All available portals provide energy-related data of India but contain data only for particular resources or area and available information is non-spatial. National Renewable Energy Laboratory (NREL, U.S. Department of Energy) developed a portal (www.nrel.gov) that advances the technology to optimize energy systems. Energy Information Administration (EIA) developed a portal (www.eia.gov) for the United States. Portal contains energy-related information for U.S. and other countries. EIA is responsible for collecting, analysing and disseminating independent and impartial energy information to promote sound policymaking, efficient markets, public understanding of energy and its interaction with economy and environment in United States. Purpose of this work is to develop a prototype of a centralized web-based information system for visualisation of energy maps showing spatial and non-spatial data of electrical power generation and consumption (including renewable energy), and other energy-related infrastructure in India. Energy information system is a system for collecting, analysing and reporting of data related to energy for better energy management and resource planning. Data is collected from various sources and transformed into geospatial data format using GIS (Geographic Information System) tools. Combining GIS with web technologies provides functionality to display information using interactive maps in the browser. Web-based GIS is open source, distributed, standardized by OGC (Open Geospatial Consortium) that brings GIS technology to the general public at little or no cost (Caldeweyher et al. 2006). The WebGIS enhance decision making at the administrative, and operational levels and serves as a gateway for decision makers and general users to access the system conveniently and effectively. The hardware specifications and network architecture for this technology provides methods for publishing and accessing GIS data at high speed (Karnatak et al. 2007). It is based on client/server model. Decision makers are seeking WebGIS based solutions as they are efficient at satisfying the needs of stakeholders in terms of availability of associated collateral information. Users are not required to install any software for using WebGIS based applications. Internet /

Network connection and modern browsers are only needed by users for accessing WebGIS based systems (Sharma and Mishra, 2017). Today, Internet and Web technology has enhanced the access and dissemination of spatial data among the communities from local to Global scale (Awange, 2013). Developing a prototype of Information system for disseminating energy-related data using WebGIS technology is main goal of this work.

Visualisation of Earth observation Data and Archival System (VEDAS) is a portal to showcase scientific products from EO applications which feed into decision making system. VEDAS (https://vedas.sac.gov.in) provides access to thematic spatially enabled data repository over land and natural resource inventories generated by Space Applications Centre (SAC, ISRO) or SAC in collaboration with other participating agencies. Prototype for developing energy maps of India is taken as a case study and developed under VEDAS. Developed application facilitates users and administrators to monitor and understand energy and related parameters. It leads to better decision making and policy planning for economic development of the country.

2. Methodology

Information system development requires relevant data from one or more sources. Energy related data for development of this system is collected from various sources that are available publicly in Government portals and reports. Collected data is analysed and converted into information.

Non-spatial data is transformed into geospatial data format using developed JAVA module in which non-spatial data is combined with geometry or coordinates and then this geospatial data is stored into spatially enabled PostgreSQL database, which is a powerful, open source and relational database management system. Information is published in a WebGIS server as a web service for graphical visualization of information on an interactive map. The web application is developed to provide energy maps of India and related non-spatial data at a single portal. It is developed using open source technologies i.e. JavaScript, Angular JS and OpenLayers 3 API and deployed on Apache Tomcat server. Energy data is also disseminated using charts and tables for analysing and understanding the information. Overall methodology and flow diagram of the proposed system is shown in figure 1. Development of Information system is divided into 4 phases: Data collection, Module development for data conversion, Publishing of data in GIS server and Development of web application.

Collection of data is a crucial part of any information system. For carrying out this study and development, data related to the energy sector is used from two sources: General Review (published by Central Electricity Authority, 2014, data source: www.cea.nic.in/annualreports.html) and Energy Statistics (published by Ministry of Statistics and Programme Implementation, 2016, data source: www.mospi.nic.in/publication/energy-statistics-2016).

Data related to generation, transmission, distribution, energy loss, cost, trading and consumption of electricity by different sectors of India is used for this case study. Some of the tables used for study data for the year 2013-14 is shown in Table 1. To use GIS functionality, data must be available in the spatial format. A module is prepared in JAVA language for fetching the non-spatial data and transforming it into geospatial data, based on the geometry and stored into PostgreSQL database.

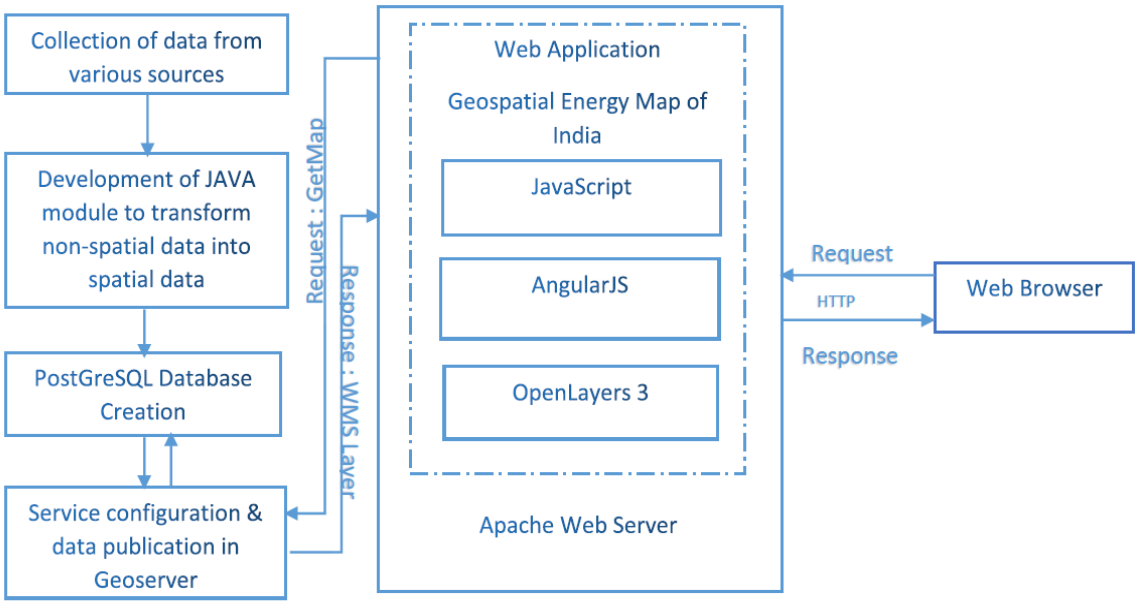

Figure 1: System flow diagram of a developed prototype

Table 1: Energy data used

No.	Data (State wise and Resource wise)
1	Installed electricity generation capacity
2	Electricity generation
3	Energy consumption
4	Peak electricity demand and supply
5	Gross electricity generation increase
6	Available power plants
	Other Data
7	Power supply and system loss
8	Transmission lines

PostGIS extension is used to add support for geographic objects in PostgreSQL. This spatially enabled PostgreSQL stores and manages non-spatial data along with its geometry or coordinates (spatial information). The WebGIS package allow to publish spatial resources and exposes them as Web services to client applications. GeoServer is JAVA based, open source WebGIS server or package which is used to share and edit geospatial data from almost all major spatial sources. It is Open Geospatial Consortium (OGC) compliant and allows flexibility in map creation and data sharing. It supports web services standards developed by OGC viz. Web Map Service (WMS), Web Feature Service (WFS), Web Coverage Service (WCS).

Web Map Service provides a simple HTTP interface for requesting map images from one or more distributed geospatial databases. It is also used to retrieve layer's metadata and server capabilities (Mishra and Sharma, 2016). Data added in PostgreSQL database is published in GeoServer as a WMS Service. As a response to the WMS request, map images are returned (i.e. JPEG, PNG, GIF) with pre-determined projection, reference and coordinate systems and with predefined associated symbols and colours. Data store is created in GeoServer to initiate a connection with PostgreSQL database. From that database, information is retrieved and published as WMS in GeoServer.

For proper planning and monitoring of energy resources, stakeholders requires an access to the energy data. To make data available and display it on a browser, WebGIS based information system is developed. It is developed using JavaScript, AngularJS and OpenLayers 3 API. JavaScript is a dynamic, open source scripting language used for building a web application. AngularJS is an open source front-end framework used for developing an application based on Model View Controller (MVC) architecture. To create maps and provide interaction with geospatial data, OpenLayers 3 API is used (Farkas, 2016). It is a lightweight JavaScript library. The developed web application contains various panels i.e. layer panel, legend panel, map panel. Layer panel displays all energy layers along with the overlay layers i.e. administrative boundary, rivers, LISS III Mosaic, RISAT Mosaic. The user can switch on or off layers using layer panel. GetMap request is sent to the server when the layer is selected. WMS service is returned as a response and displayed in a map panel. Opacity slider is added to each layer to modify the transparency of layers.

Selected layers are displayed in a map panel. The user can get feature information (i.e. energy details, layer information) by clicking on the map. GetFeatureInfo request is passed to the server with selected coordinates, which returns available information for that geometry. It provides a response in HTML format, which get displayed in a popup. Legend panel is used to provide a legend of the selected layer.

Chart, tables and tool components are developed for comparison and analysis of data. HighCharts API is used for generating user-friendly and interactive charts for a better understanding of information. For better user interaction, the toolbar is developed to provide various GIS functionalities i.e. zooming, panning, uploading/downloading files i.e. KML or GeoJSON, length/area calculator, feature drawing (point, line and polygon). The user can also save these features in KML / GeoJSON format.

3. Results and discussions

The developed application can be useful for stakeholders and users for collecting, analysing and disseminating energy information to promote sound policymaking. Better GUI and graphical representation help users to understand the information. Various electricity data layers i.e. generation, consumption, loss of electricity are available along with the overlay layers. Figure 2 shows the user interface of the web application. Layer panel containing layers related to electricity data and overlay data is shown. The user can add or remove layers using on/off checkbox. Map area displays all selected layers. Data of electricity generation by various fuels (thermal, hydro, steam, renewable) for each state is disseminated using pie chart, which can help users to analyse which mode is used most for electricity generation. i.e. Bihar, Tripura, Sikkim generate electricity mostly using renewable energy sources while other states i.e. Gujarat, Maharashtra generate electricity using thermal resources. In figure 3, various layers are stacked. The user can get feature information by clicking on a map. Feature Information of selected layers can be displayed using popup for selected location on map. The chart displayed in the figure shows a comparison of state wise energy consumption data for different years which will help in analysing the change in energy demand and supply. Based on given analysis, administrators can take measures for increasing supply or installation of power plants in the states having high energy consumption. Data of available transmission lines is also disseminated as an overlay layer in map. Figure 4 shows the data of all energy layers in tabular format, which helps in analysis of data. Legend panel shows legends for selected layers for better visual understanding of the data. Figure 5 displays layers related to solar power plants along with the opacity slider. The chart provides details of month wise installed capacity of the solar power plant.

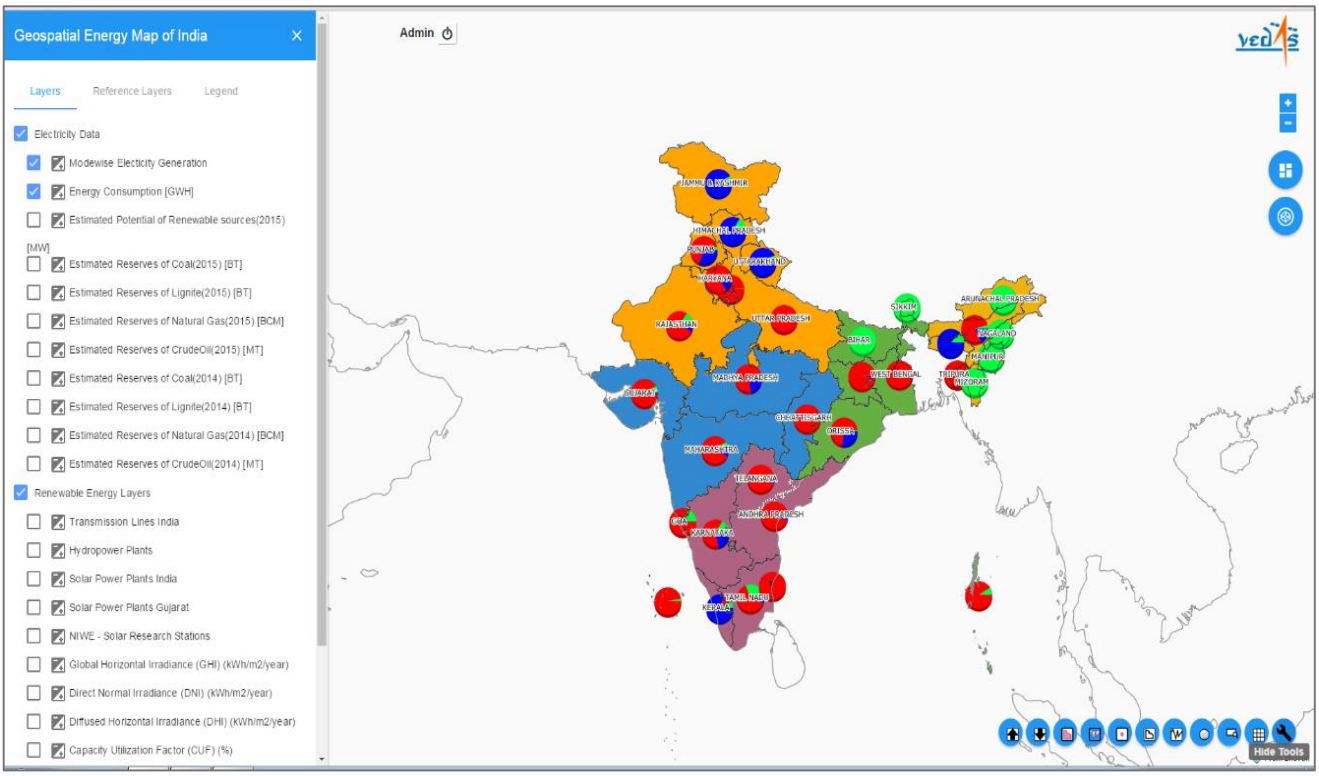

Figure 2: User interface for WebGIS based energy sector Information System

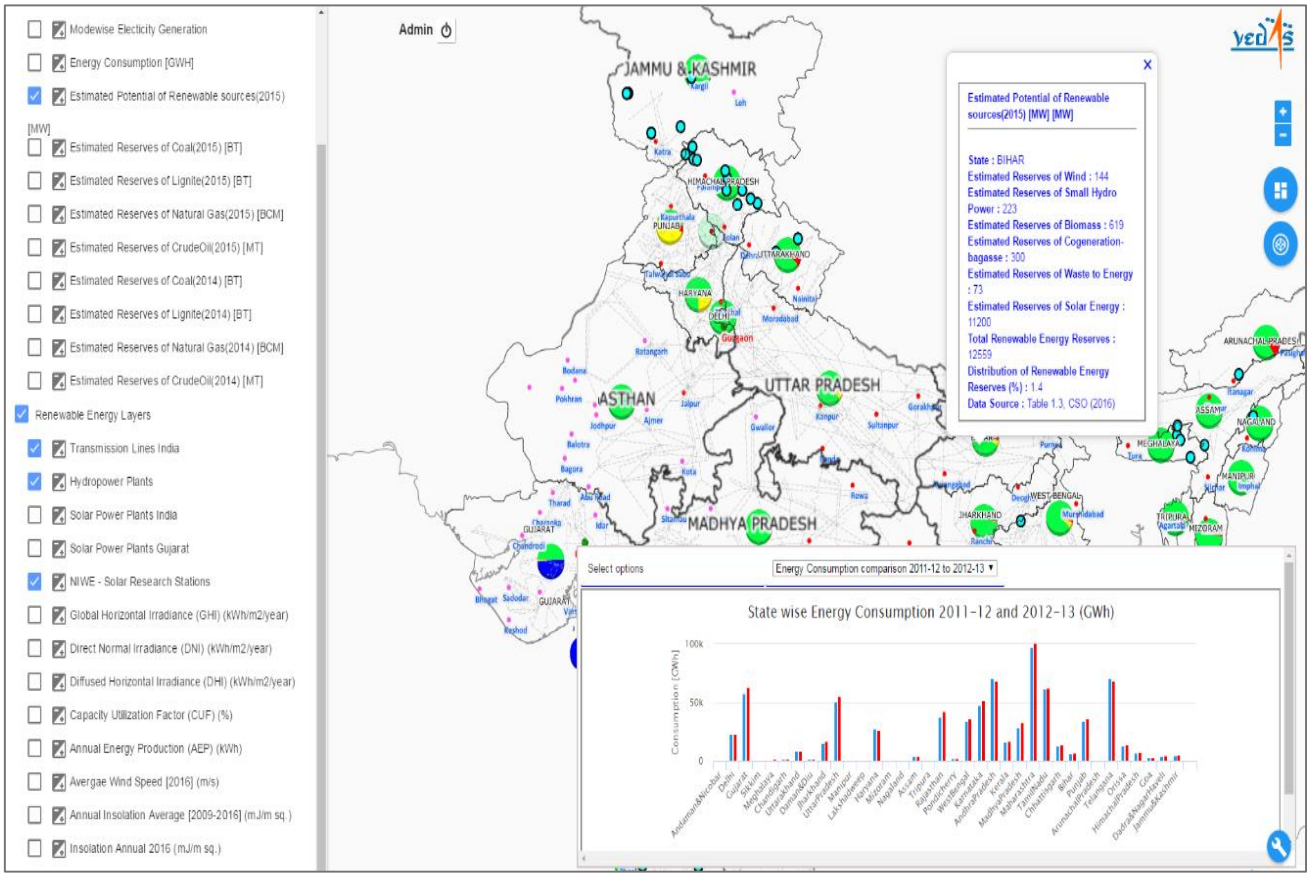

Figure 3: Layers of an estimated potential of renewable sources and transmission lines along with an energy consumption comparison chart

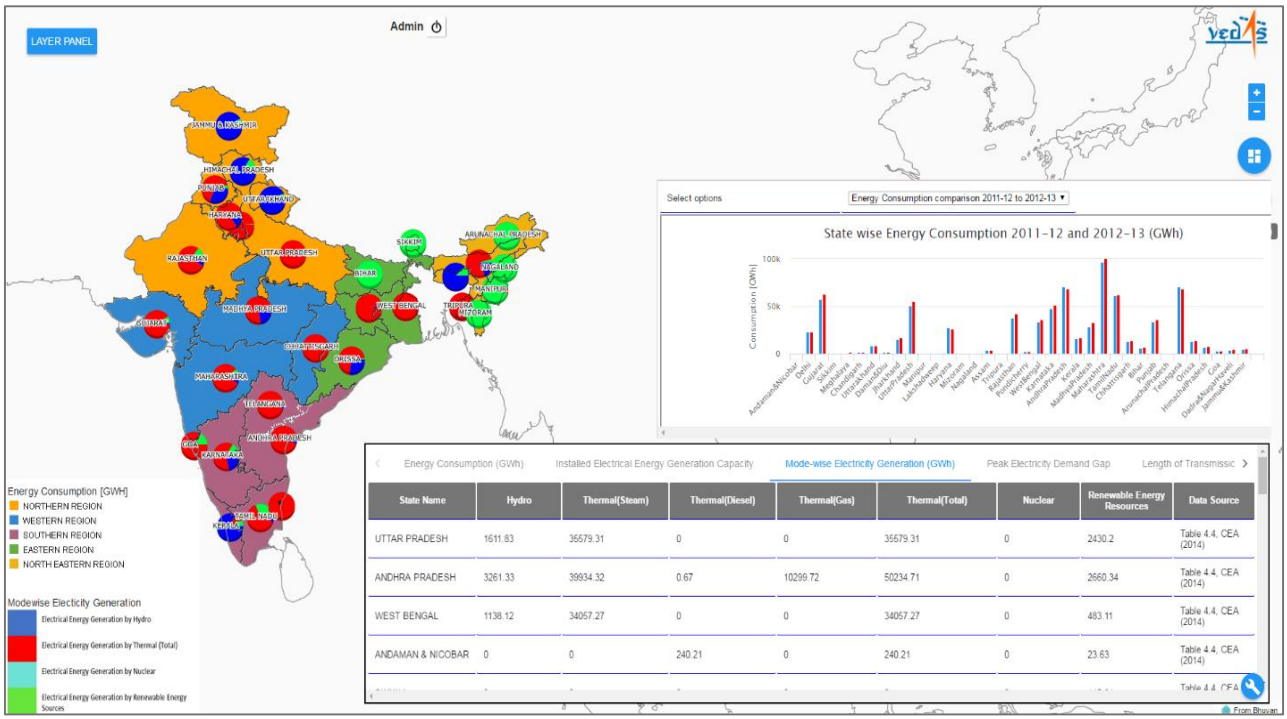

Figure 4: Layer preview along with legends and information in the chart and tabular format

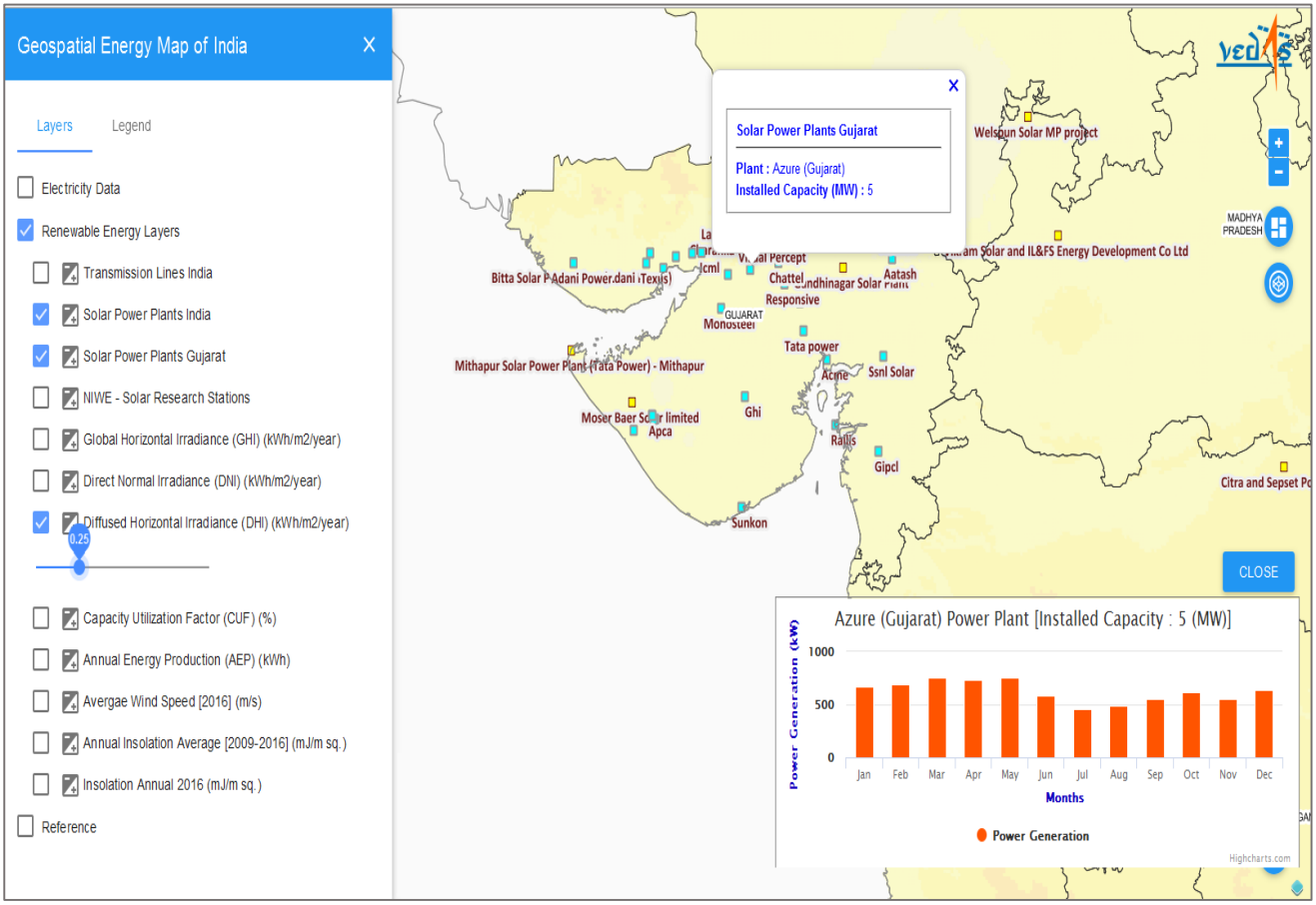

Figure 5: Chart demonstrating monthly installation capacity of the selected solar power plant

4. Conclusion

Spatially enabled PostgreSQL database creation facilitates in maintaining energy sector data centrally. Redundant data problem is solved as data has geometry as a key index. Users can visualize and analyse relevant energy data using this type of developed centralized system instead of searching from various sources. WebGIS based information system provides distributed access to the information, which removes the dependency of hardware or software to be installed at the user end. Use of open source GIS technology helps end users in retrieving information at lower or no cost. Accessing energy related data would help administrators in better decision-making and policy planning to satisfy the ever-growing energy demands. Such information can be used for development of new infrastructures of energy generation and reduce the dependency on imports of energy. As information system provides details of conventional and renewable energy resources, statistical analysis of usage of all resources will promote the utilization of green energy, which can minimize the damages done to the environment. Gathering data and making it available in graphical view can help users in providing an analytical overview of the current trends to understand and save energy.

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