Bibliography of Open Data on Indian Power Sector: Part 1: Electrical Systems, Operations and Markets

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***Abstract*—In the fast evolving world of information age, the value of open data is being recognized around the world. The information and communication technologies are making it easier to collect and store data. The consequent use of this data is leading to smartness in the respective sectors. Since power infrastructure is critical for national security, the availability and access to data is one of the hurdle for researchers in power sector. However, due to paradigm shift in Government's view of open data, paired with advancements in technology proactive dissemination of data on various sectors in India, including power sector, has become a reality. Thus this two part paper attempts to compile a bibliography of all such data sources, to the extent possible, pertaining to power sector of India. Part 1 covers the electrical systems operations and markets. Part 2 covers the regulations, standards and smart grids. It is believed that this will help all the stakeholders including researchers in knowing what kind of data is available and possibly give them new ideas in applying this data in their respective research. This paper organizes the data sources into various domains and also discusses recent developments in the open data movement across the world and how Indian power sector can be benefited from the same.**

I. Introduction

On 17th March 2012, the Government of India (GoI) has passed a gazette notification on national data sharing and accessibility policy (NDSAP) [1]. This policy calls for proactive dissemination of government owned data through the open government data (OGD) platform [1]. The scope of this policy applies to all data and information created, generated, collected and archived using public funds provided by GoI directly or through authorized agencies by various ministries / departments / organizations / agencies and autonomous bodies. The data pertaining to Indian power sector falls under the purview of ministry of power (MoP). About 513 total data sets are available as of June 2016 [2] are maintained by CEA. These data sets include power supply position, power generation, progress report of village electrification, coal statement of thermal power stations, peak demand and peak met [2]. In line with the NDSAP, the GoI has created a web directory [3], which acts as a one-point source to access all Indian government websites at all levels and from all sectors. The directory is continuously being enhanced with comments and suggestions for improvement from all stake holders. In the energy and power sector part of the web directory, as of June 2016, a list of about 243 sources are mentioned including the central and state agencies [4].

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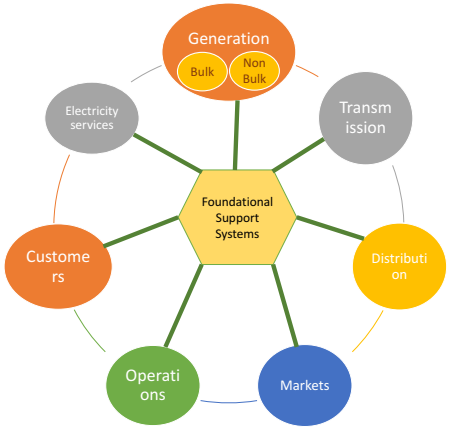

Fig. 1. IEEE Smart Grid conceptual model

Government open data would be a tremendous resource for researchers. The advantages of having open data, how to set up open data and utilization of open data is described in [5]. The data available could be used as a test case data for performing research aiming at the country scenario. The aim of this paper is to create awareness about the Indian power sector data that is available in public domain. Fig.1 shows the ieee conceptual model. The data available in the public domain is categorized based on this ieee smart grid conceptual model [6]. Part-1 concentrates on the domains of this model.

II. Institutional Framework for Indian Power Sector

In this section, we shall briefly introduce various institutions that are governing the development of Indian power sector. The institutional framework under MoP is outlined in following subsections covering a partial list of major bodies.

A. Statutory Bodies

The central electricity authority (CEA), serves as advisory body on technical and economical matters. The central electricity regulatory commission (CERC) is responsible for creation of regulations governing the central power sector. At state level the state electricity regulatory commissions (SERC) take care of regulating the tariffs and grant of licenses. Appellate tribunal for electricity (APTEL) is for hearing cases against regulatory commissions. The central transmission utility (CTU) is responsible for transmission of energy through inter-state transmission system and discharge all functions of planning and coordination relating to inter-state transmission system. The state transmission utility (STU) undertakes transmission of energy through intra-state transmission system and discharge all functions of planning and coordination. The Indian national grid is an interconnection of five regional grids, which are in-turn inter connections of state grids. The national load dispatch center (NLDC) performs optimum scheduling and dispatch of electricity among the regions. Similarly at regional and state levels the regional load dispatch centers (RLDCs) and state load dispatch centers (SLDCs) have been constituted. The bureau of energy efficiency (BEE) is responsible for spearheading the improvement of energy efficiency through regulatory and promotional instruments.

B. Autonomous Bodies

The central power research institute (CPRI) serves as a national laboratory for undertaking applied research in electric power engineering besides functioning as an independent national testing and certification authority for electrical equipment and components to ensure reliability and improve, innovate and develop new products. The national power training institute (NPTI) is the national apex body for the human resources development of power sector personnel in India.

C. Public Sector Undertakings

The national thermal power corporation (NTPC) is the largest power generating company in India, with the objective of building large size thermal power stations, along with associated transmission systems, to accelerate the integrated development of power sector in the country. The national hydro power corporation (NHPC) aims to harness the vast hydro, tidal and wind potential of the country to produce cheap / pollution-free and inexhaustible power. NHPC plays a significant role in the integrated and efficient development of hydroelectric, tidal and wind power in the central sector covering all aspects such as investigation, planning, designs, construction, operation and maintenance of hydroelectric, tidal and wind power projects. The power grid corporation of India (POWER GRID) is mandated to establish and operate regional and national power grids to facilitate transfer of power within and across the regions with reliability, security and economy on sound commercial principles. The power finance corporation (PFC) is a financial institution dedicated to the growth and overall development of the power sector. The Rural electrification corporation(REC) provides financial assistance for rural electrification in the country. North eastern electric power corporation (NEEPCO) is charged with development of large power potential of the north eastern region of the country.

III. Data based on IEEE Smart Grid Conceptual Model

According to the IEEE smart grid conceptual model [6], the power sector can be divided into conceptual domains. In this section we shall take up each domain and explore the public data available pertaining to that domain.

A. Bulk Generation

A monthly executive summary report [7] published by central electricity authority (CEA) provides an overview of Indian power sector.This report also provides the peak demand of that month along with the peak met in that month. This data will be useful for the researchers to observe which month the more peak is there. Also this data is useful for forecasting of the real time data for India. The daily generation details are published by central electricity authority(CEA) in [8]. There are sub reports in which daily generation details all over India are presented. These generation details include the region wise and also classified based on the type of fuel used for generation. In [8] daily outage reports of the generating stations is also presented. The overall installed capacity of generation of India is available on [9]. The power maps are provided by which the location of the generation stations can be known in [10]. By using this power station location and by having the solar data of that location based on latitude and longitude in [11], backup supply for the generating station and the economic analysis can be obtained. The monthly power reports of CEA will provide the details of power generation of each power station individually in [12]. The performance of the nuclear power stations is presented in [13]. In [12] the energy exchange details between regions are presented. This data will be helpful for researchers who are working in the are of improvement of performance of nuclear power plants in India. The monthly aggregate wind generation data is made available by synergy in [14].

B. Transmission

The transmission review reports are presented by CEA in [15]. In [10] the details of different types of transmission lines and transmission line ratings used in India are specified. Also the location of HVDC lines and high rated transmission lines can be obtained. The transmission outages data is being provided by power grid corporation of India limited (PGCIL) in [16]. This data is available in excel in which region wise transmission line outages are presented. The duration of outage can also be obtained from [16]. The reason for the transmission outage is also detailed in the presented excel sheet by PGCIL. Along with the central transmission there is a state wise transmission system which are called as transcos. The andhra pradesh transmission company publishes monthly report on transmission losses, considering as gencos as input and discoms as output [17]. The technical specifications of

the conductors and the transmission equipment of the andhra pradesh transmission is available at [18]. Similarly by accessing to the corresponding state transcos websites similar type of data is available in public domain.

C. Distribution

Distribution is important link in the value chain of electricity supply, as this domain acts as interface with the end consumer. It is the revenue generator for the entire sector. The integrated power development scheme (IPDS) approved by the central government in november 2014, aims to (i) strengthening distribution networks in urban areas, (ii) metering of distribution transformers, feeders, consumers in urban area and (ii) IT enablement of distribution sector [19]. The MoP runs a webportal for providing the latest updates on the progress of the scheme [20]. Another important scheme focused on rural areas has also been approved in november 2014, namely, Deendayal upadhayaya gram jyothi yojana (DUGJY). This scheme aims to (i) separate agricultural and non-agricultural feeders, (ii) strengthening of distribution network in rural areas, (iii) metering of distribution transformers, feeders, consumers in rural area and (ii) rural electrification. The MoP runs a webportal for providing the latest updates on DUGJY at [21]. According to the portal, as of June 2016, out of 5,97,464 census villages 5,87,440 (98.3%) villages have been electrified. Limiting of aggregated technical and commercial (AT&C) losses is one of the primary challenges of the Indian distribution sector. As per the IPDS scheme, trajectory of AT&C losses from 2013 to 2022, for all the government owned discoms is available at [22]. The performance of state utilities presented by power finance corporation (PFC) and it is presented in [23]. Also it contains the individual utility performance throughout India. The ratings of different utilities in India are presented in [24].

Apart from the above mentioned government utilities, there are many private distribution companies operating in various parts of the country. BSES is the private distribution utility serving in the state of Delhi, with total registered consumers of 3.55 million as of March 2015. With aggressive investments in the distribution infrastructure the AT&C losses have been significantly reduced from 63.1% in 2002 to 18.9% in 2015 in the central and east Delhi. Similarly in the south and west regions the corresponding reduction is 51.5% to 13.9% [25]. BSES though its consumer web portal [26], provides information on tariffs, outages, bill payments, customer support, maintenance schedules, technical specifications of meters. Apart from this, detailed geographical information system (GIS) maps of the distribution network in the entire distribution regions of Delhi served by BSES are also made available [27]. Reliance energy is another such progressive private discom which provides similar information on their portal. An information guide is also provided for education of consumers [28].

D. System Operation

The power system operation corporation limited (POSOCO) is a subsidiary of power grid corporation of India (PGCIL). POSOCO is responsible for integrated operation of the national grid in efficient, reliable and secure manner. It is comprised of national load despatch center (NLDC), and 5 regional load despatch centers (RLDC). These RLDCs will operate with collaboration with state load despatch centers (SLDCs). The forecasted peak demand of each of the states of India based on last 3 years data is presented in [29]. The national grid frequency profile for each day since the beginning of 2015 is available at [30]. POSOCO releases a daily report of the power system [31], which includes the data on maximum demand met, shortage during maximum demand by each state, international and inter-regional power exchanges on each day since april 2013 onwards. This wealth of information is readily available for further research and analysis. POSOCO also releases weekly report summarising week data pertaining to peak hour shortage, energy consumption data of each states, generation and load losses data are presented in [32]. In [33] monthly report provides details on data regarding the demand met, import/export of power between regions, frequency, losses. State estimation of the bad data in Indian power sector is presented in [34]. Individual states load factor, synchrophasors data calculations are presented in [34]. The angular difference of power in India is presented in [35]. The overall system reliability indices are presented in [36]. Another interesting and detailed monthly report published by POSOCO is known as the operational feedback report [37], which presents the big picture of system operation, planning of national grid, transmission constraints, major grid events etc. Another useful resource is a repository of various research papers [38] published by POSOCO on practical aspects of system operation. Inline with the regional dispatch centers the state load dispatch centers also publish similar type of data in their websites or web portals. The grid disturbance data of WRLDC is available at [39]. IIT bombay developed in house softwares for analysis of transient stability, load flow, SEQUEL (which is a circuit simulation platform), single machine simulation model in matlab, domestic inrush currents. These softwares are made into public domain and are available in [40]. iPDC is the phasor data concentrator which is developed based on IEEEC37.118. This software is freely available along with documentation in [41]. The wide area frequency measurement data is maintained by IIT bombay in [42]. The in house developed device is deployed across various cities and the grid frequency is monitored for every one second. This [42] maintains a database of old and new disturbances data. Along with this the source code used for frequency measurement is also made available.

E. Markets

Access to market information is key to ensure efficiency, avoid information asymmetry and increase competition in the sector. In view of this, CERC publishes both monthly and annual market monitoring reports [43] on short term power markets in India. These reports provide data on the volume of electricity transacted in short term markets versus long term markets, weighted average prices of electricity

transacted in power exchanges, comparison of prices across various regions, level of competition among licensees, number of solar renewable energy certificates transacted etc. The details of the short term transactions of electricity in India is presented in [44]. India energy exchange (IEX) [45] and power exchange of India limited (PXIL) [46] are the two major power exchanges operating in India. IEX has been publishing monthly market analysis reports [47], since 2008 till date, which present trends on market clearing prices and market clearing volumes, losses due to network congestion etc. A detailed presentation on status of Indian electricity markets [48] as of June 2016 has been published by IEX. Apart from this the day ahead market prices for all the price areas in India are also made available at [49]. Similarly, PXIL also publishes detailed market volume profile report including day ahead market information [50]. The regulations regarding the ancillary services in markets are presented by nldc in [51]. The markets information pertaining to short term open access (STOA), long term open access (LTOA), available transfer capability (ATC) along with historical data in [52]. STOA with Bhutan and Bangladesh are presented in [53]. Another valuable source of information on Indian power markets is provided by REConnect Energy which is India's largest REC trading company. The monthly news letters, white papers, research articles [54] published by REConnect are deemed to be quire informative for researchers in renewable power markets. REConnect energy through its innovative platform called clickpower.in [55], enables open access consumers and generators to explore the best available options for procuring greener electricity, by providing detailed analytics on power exchange market transactions thus facilitating exploration of best possible options. A geographical map showing the prices of short term open access power is available at [56], this will enable the discoms to see how much they can save by transacting in open access. The modelling and representation of STOA transactions, leading to better visualisation and understanding of market situation is described in [57].

F. Consumer and Electricity Services

Customer satisfaction is considered as one of the goals in the India power sector. Also in order to achieve the prosumer concept there should be a transparent interaction between customer and the service providers. Most of the state government distribution companies are just providing the bill payment gateway in their respective website. But the information about the scheduled maintenace, outages are not being published presently. But the private distribution companies like bombay suburban electric supply (BSES) are maintaining a customer portal [58] in which the electricity consumers under the BSES for logging of complaints, paying bills online etc. In the similar lines tata power distribution company also maintains a customer portal [59] where demand side management, details about outages and maintenance are published.

IV. Discussion and Conclusion

In this part 1 of the paper several useful resources on open data available in public domain pertaining to the traditional electrical domains, namely, bulk generation, transmission, distribution, markets, system operation, end consumers and services have been cited. While part 2 of the paper focuses on regulations, standards, smart grids etc. Contrary to the popular view that - it is difficult to obtain data on power sector data, it is observed that, many resources exist where not only the past but also the present scenario is made available online. Various stakeholders, and specifically budding researchers in this field will benefit from understanding the practical aspects of power sector in India by going through the references cited in this bibliography. This practical knowledge will complement the theoretical knowledge gained from well established text books on power system analysis. While effort has been made in compiling an exhaustive list of useful resources, due to the vastness of the power sector and due to space limitation of the paper, this bibliography is far from being complete, and should only be considered as an initial but growing list. The authors shall gladly welcome and appreciate comments on this paper, suggestions for new resources to be included in the bibliography, any omissions or corrections needed in this paper. This paper is to be viewed as a living document with regular updates.

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