Factors and Constraints for implementing a Unified Data Platform for Operational Intelligence and Analysis of the Power Sector

Pratik Ghosh, Ratna Banerjee, Vinay Kandpal, Jacob T. Verghese

Abstract: ***The research tries to identify the various factors that need to be integrated to implement a Unified Data Platform (UDP) for the power sector and its interoperations.Data and tools from generation, transmission, distribution and trading were readily available but in silos and we added to it the complexity of interoperability between stakeholders affecting the organizations, applications, information systems, social, economic, regulatory and technical infrastructure. The different data silos were studied to identify the factors which need to be analysed and integrated for these silos to interoperate with each other for attaining operational excellence in a competitive environment.The research was important as the last few decades have seen an organic growth of the power sector in India. This growth inherently bought with it the requirement for humongous enhancement of existing systems, restructuring of the sector, modification of the policies and develop frameworks to handle the scale of future capacities. The integration and interconnection of different stakeholders in the sector has increased the quantum of software, hardware, tools and data by manifold. The unification of data at a higher level will improve the operational efficiencies and reduce the losses at silos level due to lack of data unification.***

Keywords: Unified Data Platform, Interoperability, Power Sector, Information System, Data Analytics, Operational Intelligence

I. INTRODUCTION

There is a data deluge and a data revolution in all sectors of life and industries. The data produced since early civilization till 2003 is five Exabyte, and this is the same data increased over next two year. As per IDC records in 2011, data volume globally has reached 1.8 Zettabytes, which is close per person data of 200 Gigabytes across the globe. The amount of digital data growing constantly and is projected to increase at a speed of 40% annually for next few years [1] [2]. India, due to its large geographic spread and the scattered availability of natural resources had to design distributed load centers across the regions making east and northeast power surplus whereas northwest and south being power deficient. The power sector is a huge collection of data networks spanning across generation, transmission, distribution, retail supply and trading as shown in figure-1.

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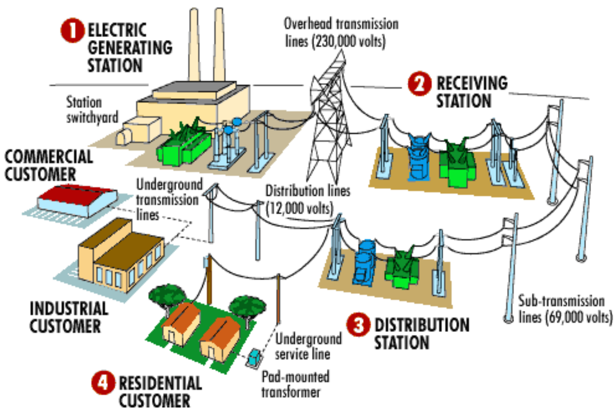
Monitoring the grid on real-time is vital for optimal operation, to minimize blackouts and grid tripping and to manage the huge and hierarchical network of load despatch centers and facilities across the country. There is a greater shift across the globe for smart grid, smart substations, hybrid and electric vehicle charging station, the power sector is going to produce larger sets of complex and dynamic data in the coming years. The data from smart grid will require quick response for faults, load curves and real time data management. Though the current data management and analytic system provides opportunities mining out insights for the power system, the lack of a unified data platform hinders the efficient data integration and module deployment [3] for operational intelligence and analysis of the power sector.



Source: Google

Figure-1 Typical power sector structure

The challenge that the smart-grid and modern power plant management systems or energy management systems (EMS) face today are the complexity of numerous disconnected network and their management on numerous platform which act in silos whereas the activities in a power system depend upon information relating to the state of the power network and their interconnection.Individual tools, software and models record existing network elements in power sector and its infrastructure layers. Records are kept for generation, transmission and distribution equipment in their respective silos. This distributed data approach has disadvantages when it comes to real network integration as independent system use diverse models and standards which make the overall network management difficult. Energy management is not accurate due to disconnected models and data.

This also increases the data inconsistencies which result from the disconnected or duplication of information in different silos. All these systems are data dependent and require communication of data between the independent systems. The analysis of data has barriers and becomes very complex if carried out in the silos. These barriers can be removed by designing a Unified Data Platform (UDP) to manage the huge interconnection of data, application, protocols and infrastructure across the intra-regional power network. A data platform designed to store, manage and analyze the humongous data to reveal the knowledge of unseen patterns which are hidden in these datasets and utilize them for making strategic, tactical and operational decisions. The UDP needs to be designed to facilitate seamless interface between the systems available in silos by standardizing data and information exchange. It should define methods and protocols for better interface between applications, robust interconnectivity and to reduce the number of data adapters for speed and reliability. We can clearly state that the impact due to lack of Unified Data Platform, for current and future data analysis of operational parameters across the power sector is leading to decision delays, inefficient operations and losses.

The segments of the Power Sector as in figure-2 were structured like a vertical hierarchy for the State Electricity Boards as depicted in figure-3.

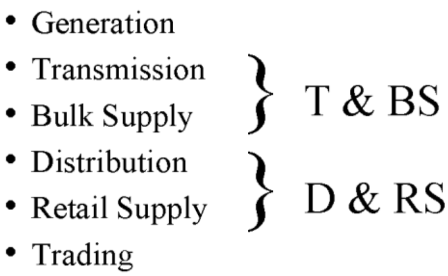


Figure-2

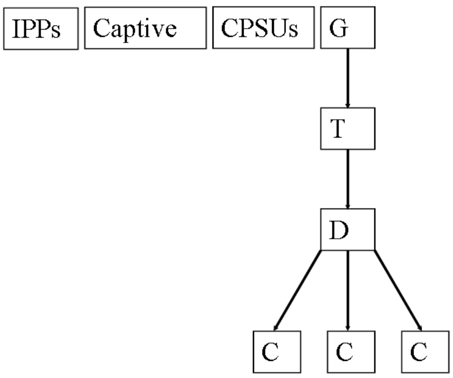


Figure-3

The same was restructured pre Electricity Act 2003 as figure-4 and with the emerging scenario post Electricity Act 2003 as figure-5.

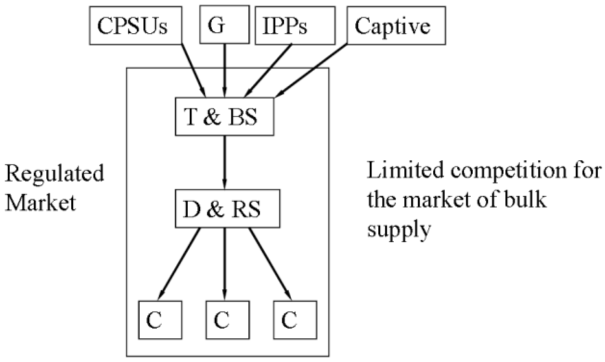


Figure-4

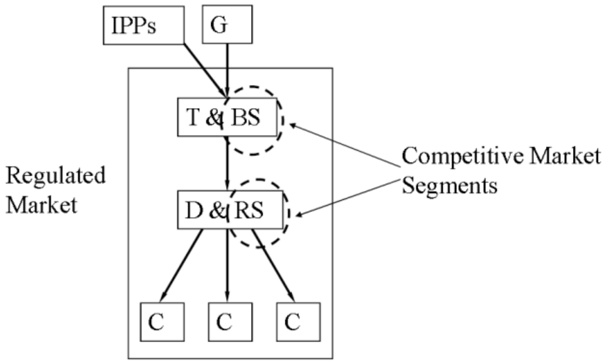


Figure-5

To operate smoothly across this large geography and necessary periodic restructuring, the power grid is controlled at three tier hierarchy namely National, Regional and State levels. Major effort for unification of operation and control was started in early nineties and the protocol Unified Load Despatch & Communication (ULDC) was designed and defined to streamline the power sector for efficient monitoring, operation and controlling in a united manner. The data was provided from the National Load Despatch Center, Regional Load Despatch Center and State Load Despatch Center.

Despite the ULDC structure, hindrances arose due to the fact that utilities across the sector are using heterogeneous infrastructure, vendor specific hardware with proprietary software, modified Inter Control Center Protocol (ICCP), and lack of common standards which make it difficult for seamless and unified data exchange resulting in inefficient operation of the grid.

These barriers can be removed by designing a Unified Data Platform (UDP) to manage the huge interconnection of data, application, protocols and infrastructure across the intra-regional power network. The lack of Unified Data Platform, for current and future data analysis of operational parameters across the power sector is leading to decision delays, inefficient operations and losses.

The UDP needs to be designed to facilitate seamless interface between the systems available in silos by standardizing data and information exchange. The UDP should define methods and protocols for better interface between applications, robust interconnectivity and to reduce the number of data adapters for speed and reliability.

II. PROBLEM STATEMENT

To identify the structured and unstructured factors that need to be incorporated for a seamless Unified Data Platform for managing information coming from various data sources like economic, social, regulation, policies, market, consumers, competition, organization, application, information system and technical infrastructure to name a few. Though data management tools are present in silos, the available literature studied and research done does not provide evidence related to Unified Data Platform across generation, transmission, distribution and trading in Indian power sector. We can summarise the problem as the "Lack of Unified Data Platform, for data analysis of operational parameters across the power sector is leading to decision delays, inefficient operations and losses".

III. REVIEW OF LITERATURE

In the light of the above business problem, extensive literature review and research was carried out to identify the factors that needs to be included on a Unified Data Platform across generation, transmission, distribution and trading in the Indian power sector. The literature review of the emerging technologies of Data Analytics with relevance to power sector was done to understand the key issues and concept of a connected world Data Acquisition Systems, automation solutions, smart and intelligent systems like smart meters and smart grids etc. Various gaps were identified as per table-1 in the literature review which was then studied for identifying the factors and constraints for implementing a Unified Data Platform. It is observed that data flow from various points like capacity management, grid data, power trading data, consumer data, smart devices data, energy management systems, asset management data, cost – revenue and billing data, system monitoring data etc. It is also observed that numerous tools and methods are available for each sub-sector like Generation, Transmission, Distribution, Demand Side Management [5] and Regulations.

Despite the ULDC structure defined earlier, data flow issues arose due to the fact that utilities across the sector are using heterogeneous infrastructure, vendor specific hardware with proprietary software, modified Inter Control Center Protocol (ICCP), and lack of common standards which make it difficult for seamless and unified data exchange resulting in inefficient operation of the grid.

The easy availability of high speed and less expensive computers today which present the new possibilities for the power utilities to use advanced computer based performance analysis, optimisation strategies, thermodynamic and electrical model designing and development of robust energy management systems. The modern system use methodologies ranging from artificial intelligence to neural networks to expert systems.

Lot of focus and new policies has been implemented by GOI to provide assistance to states employing various schemes for improving the distribution sector like

- Integrated Power Development Scheme (IPDS)
- Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY)
- National Electricity Fund (NEF)
- Financial Restructuring Scheme
- The objectives of the various schemes are:
- IT enablement of sector
- Strengthening of T&D networks in the urban areas
- Strengthening of T&D networks in the rural areas
- Metering of distribution / consumers in the urban area

No	Theme	Gaps	Inference
1	Data Management	▪ Data and tools available in silos; ▪ No evidence found related to unified data platform for analysis of operational parameters at the utility level	Data needs to be unified on a common platform for analysis of the power sector
2	Technical Capability	▪ The legacy systems have old data and software protocols ▪ These might not be capable to exchange data across the network	Hardware and software budget needs to be assigned for upgradation of the legacy system
3	Information Sharing	▪ There is little / no evidence of information sharing and communication between generation, transmission, distribution, trading ▪ There is poor data analysis, and inadequate monitoring at power sector level	National level Regulatory Framework needed to address the technical requirement of data communication across the sector
4	Business Implication	▪ There is a huge impact of decision delays across the sector but there is no readily available data for it ▪ Effects of delays in silo are available for many issues and incidences	Financial benefits needs to be highlighted to promote and implement a unified data platform across the sector
5	Existing Data Frameworks	▪ Study the existing tools available in Silos was done for their pros and cons	Process Map to be developed for base lining the communication system across the network to integrate data from the silos

Table -1 Themes from literature review, gaps and inference

- Metering of distribution / consumers in the rural area
- Separation of non-agriculture and agriculture consumers and feeders
- Rural Electrification Programs

The literature review of the existing and emerging technologies of power sector and methods for developing interfaces for data management and analytics was done. The key parameters and technologies for a connected sector including data acquisition systems, automation solutions, smart and intelligent systems were considered for research.

IV. RESEARCH OBJECTIVE

It is necessary to undertake detailed research to identify the factors responsible for non-existence of Unified Data Platform across generation, transmission, distribution and trading in Indian power sector.
This research relied on the information gathered through the literature survey, semi-structured interviews of experts from generation, transmission, distribution and trading sectors in India and international best practices and experiences from countries, especially BRICS.

V. RESEARCH METHODOLOGY

This research relied on the information gathered through the literature survey, semi-structured interviews of experts from generation, transmission, distribution and trading sectors in India and international best practices and experiences from other countries. Relying upon factors for financial viability and regulatory compliance, this study proposes a process map for the data unification in the power sector. For that study of existing data platforms and its ability to integrate with a unified data platform for holistic analysis of power sector become a necessity. Motivation for research is to increase operational efficiency, reduce data lags; that leads to operational and business loss.
Research was conducted to identify the structured and unstructured factors that need to be incorporated for a seamless and Unified Data Platform for managing information coming from various data sources like economic, social, regulation, policies, market, consumers, competition, organization, application, information system and technical infrastructure to name a few. Exploratory Research design and expert survey was conducted in Semi Structured interview form to identify factors distinctive for each sub sector (Silo) and sector as a whole.

Exploratory Research Design

- Identified variables from literature survey and analysis of data applications in silos
- Used Grounded Theory Methodology (with conceptual lens by Charmiz)
- Prepared the Conceptual Lens
- Prepared the interview schedule for domain experts
- Conducted one-to-one un-structured interview and record response
- Made a list of the different type of information from the notes
- Identified and coded (key points of the data) using QDA-Miner as a tool as one sample of data coding shown in figure-6
- Grouped similar concepts into Categories
- Continued with the loop till data saturation was reached

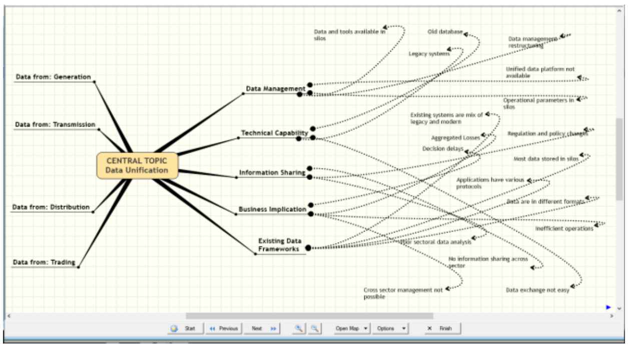


Figure-6 Coding Data Points

Primary data was collected through semi structured interviews and one-to-one interactions and the Secondary data to be collected through Reports of MoP, GoI, Planning Commission of India, Central Electricity Authority (CEA), Central Electricity Regulatory Commission (CERC), Scholarly journals, whitepapers etc.

VI. ANALYSIS & INTERPRETATION

For a Unified Data Platform we have to interface and manage information from various data sources like economic, social, regulation, policies, market, consumers, competition, organization, application, information system and technical infrastructure to name a few that needs to be interfaced to communicate and share data for analysis.
Most organizations have distributed applications and their interactions should be ensured by an inter application protocol. Similarly, the technical interactions need to be ensured by device level protocols. The data from social, economic and policies guidelines have their own roles in interactions which regulate the sector. We must ensure that interactions between the various levels are also achieved independently. Therefore the system should allow the developer to choose standards and levels based on priorities, policies and regulations.
While the ownership of policy and regulation lies with the government, the emergence of new Electricity Acts and their amendments raise many fundamental questions and new set of data gets introduced for analysis.
In this paper we try to identify few of the data factors and interfaces that we need to provide with the Unified Data Platform for increasing operational excellence, competition and reliability of the power sector as a whole. Some of them are listed below though this is just an indicative subset of the actual data that might go into the UDP system.
The various systems that exist today were analysed to assess their viability and compatibility to connect with a Unified Data Platform. Some of the systems in silos discussed with users, vendors and experts and was analysed are shown in table-2.

A. *Organizational Interfaces*

- Link the large network of generation, transmission and distribution units scattered across large geographical area
- Control level platform for the operation of the network
- Management of the distributed and area wise control centers

Generation	**Customer**
Plant Control System	Meter Management (AMI / AMR)
Capacity Management System	Customer Management
Energy Synchronization System	Customer Energy Management
Security Management	Energy Service Interface (HAN)
Transmission	**Operations**
Transmission RTU	Transmission Engineering
Transmission IED	Distribution Engineering
Phasor Management	Network Management System
Continuity Management	Outage Management System
Distribution	Distribution Operator
Distribution RTU or IED	Energy Storage Management
Field Operation System	Load Management System
Geographic Information System	Transmission SCADA
Distributed Information	Distribution SCADA
Sensors and Metering System	Energy Management System
Data Collection System	Bulk Storage Management
Service Provider	Meter, Billing, Back Office
Retail Energy Management	Customer Information System
Billing Management	Customer Service Interface
Energy Service Provider System	Customer Portal and Access
Third Party Interface	

Table-2 Data Systems in silos

B. *Technical Interfaces*

- Technical investments and returns
- Assets not widely traded
- Reduction of transaction costs
- High sunk costs
- Network externalities

C. *Economic Regulation and Interfaces*

- Quality of services
- Financial performance under public ownership
- Financial performance under private ownership
- Price of power generation and supply
- Quantity - spectrum, banking of power
- Entry & Exit policies
- Investment – capacity expansion
- Access to Resources – mining rights for power (coal)

D. *Application Interfaces*

- Numerous Application interface from the control room of an utility
- Interaction and storage of operating dataset
- Management of applications like SCADA, Business Process and Energy Management System
- Integration of data from different servers
- Asset management of different hardware configurations
- Software and network management developed by various programmers ranging from legacy to modern software languages on different platforms
- Application Interface for the unified data platform so that different applications communicate in a common methodology, integrated and platform neutral
- Standardize services and applications using information exchange protocols
- Achieve application interoperability
- Manage Service Orientated Architecture and Event Driven Architecture
- Design options to scale and integrate the UDP

E. *Regulatory Interfaces*

- Comply Central Electricity and Regulatory Commission (CERC) mandate for reporting
- Provide data from generation, transmission and distribution of the power network
- Comply to the ULDC scheme which defines a high level hierarchical organization structure
- Comply compatibility between all the tools, sensors, hardware and software used

F. *Socio-economic and Organizational Interfaces*

- The need of a central management and control system
- Erstwhile owned by government but now moving towards joint public private organizations
- Citizen right is important to ensure a minimum supply of power daily

G. *Information Interfaces*

- Develop information models and protocols
- Defined variable and naming schema for data storage and processing
- Mapping of information exchange between devices and application
- Manage multiple mapping due to different protocols, programs, platforms and systems

- Define standard information model to be followed by vendors
- Represent all the system data like primitive data types, aggregated data types, naming schema and universally identifiable conventions

H. Hardware and Device Interfaces

- Identify and map the physical medium of connectivity for data transfer between various devices and networks
- Establish syntactic data interoperability
- Manage hard wired communication networks on standard protocols for data transfer
- Design scalable and modern IP based Intelligent Electronic Device
- Define unique identification for devices and interfaces

VII. CONCLUSION

The various factors and constraints to be considered for implementation of a Unified Data Platform for Operational Intelligence and Analysis of the Power Sector were identified. It was identified that interactions are present at various level between systems installed at power grid and is important for defining the standard methods for a robust and reliable data platform to handle the heterogeneous data, application interfaces, legacy and future architecture, be scalable, plug & play capability of hardware, software and services. The vendors and developers of upcoming systems must comply and provide UDP adapters and interface necessary for transferring data and information in a compatible and accessible manner across the sector.

The constituents that would enhance the implementation of a Unified Data Platform are

(i) Regulatory Framework, (ii) Financial Parameters, (iii) Application Interfaces, (iv) Hardware & Device Interfaces.

These broad constituent were further sub-divided into interfaces that need to be integral part of the Unified Data Platform. The study fills a literature gap and proposes a unified data platform and the factors that need to be interconnected for better interoperability of the power sector starting from generation to the end-user. The data can be used to extract the dynamic state of the power plant and processed for numerous analysis like fault diagnosis, performance management, optimization systems, load forecasting. The unified data analysis can lead to economic advantages for each stake holders of the power sector as well as their consumers. The data history and pattern analysis can be used for forecasting and prediction system. The network can be used for the demand side management and plan for future generation based on forecasts. This will help utilities save millions in revenue.

The application range of intelligent output can be numerous if we design the Platform adaptable and flexible for current and future requirement. To achieve this, we not only need to upgrade or modify our existing systems in power sector but also need policy level changes to ease the flow of data across the sector.

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D. Abbreviations

1. NLDC – National Load Despatch Center
2. RLDC – Regional Load Despatch Center
3. SLDC – State Load Despatch Center
4. CEA – Central Electricity Authority
5. CERC – Central Electricity Regulatory Commission
6. ULDC – Unified Load Despatch & Communication
7. IED –Intelligent Electronic Device

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Fourth Author Profile Dr. Jacob T. Verghese, holds a PhD from BITS Pilani and completed his Mechanical Engineering first year with merit scholarship from IIT, Madras in 1964-66 followed by graduation from Indian Railways Institute for Mechanical and Electrical Engineering, Jamalpur in 1966-70. He has held various positions in Indian Railways from 1970 to 1995 when he took voluntary retirement as Board Member. From 2001 till date he is managing the operations of STEAG Energy Services (India) Pvt. Ltd earlier as Managing Director and currently as Chairman of the Board. He is associated with national and international committees and bodies like Planning Commission for Railways, Ministry of Energy, Ministry of Railways, Ministry of Human Resource Developments, UNDP project, GTZ, Member of the Core Group to finalize curriculum for PGDM course at the newly set up Indian Institute of Management, Calicut, Excellence Enhancement Centre, society registered by Central Electricity Authority. He has a vast teaching experience conducting lectures at IIM, Calicut, National Productivity Council, Institute of Applied Manpower Research, Railway Staff College, Punjab National Bank, Indian Institute of Technology, Delhi, St. Columbus School He has association for education and social work as Chairman Advisory Committee, Institute of Management Studies, YMCA, Vice-Chairman of the Society for the Education of the Poor, New Delhi, Member of the Executive Board and governing Council of Holy Family Hospital, New Delhi. He has held Ex-Officio positions as Member of the Central Apprenticeship Council, Member of Northern Indian Technical Education Committee, Member of the Governing Council of the Institute of Applied Manpower Research, New Delhi, Member Advisory Committee for the Indian Railways Centre for Advanced Maintenance Technology.

Some of his publications and papers are

- Methodology for Measuring Manpower Productivity on Indian Railways
- Trends in Staff Productivity and Tasks Ahead
- IR2000 - Turning the vision into reality
- International comparisons of productivity
- Redeployment strategies on IR-case study
- Organizational approaches to technological upgradation of Indian Railways
- Review of management training on Indian Railways
- Introduction of the computerized system of Diesel Loco spares Purchase
- Energy Conservation Measures on Indian Railways
- Measures for improving the availability of Diesel Locomotives
- Phasing out of Steam Traction by the end of 8th Plan (1994-95)
- Energy Audit of Rail Bhavan
- ‘Perspectives in Improving Management of Railways’’ for Current Science
- Management of Technological Change on Indian Railways – an Overview