International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-10, August 2019

Process Map of a Unified Data Platform for Operational Intelligence and Analysis of Power Sector

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***Abstract:** The research tries to define "Process Map" for a Unified Data Platform for the power sector and its interoperations. Data mining and analytics are playing a key role in every modern industrial and process system. The tremendous growth in the field of information technology, communication protocols and support of high performing processors of modern day computer has led to a layer of data and information which can be utilized for management and operational excellence. The different data system, communication protocols, hardware and software applications were studied to identify the factors for designing the process map.The information layer added to the conventional power sector network is studied which is an ever increasing source of data. Additional data is being added by the new generation smartgrid with its automation system that are having numerous sensors embedded in the existing power system for controlling, monitoring and operational activities. The research was important as the last few decades have seen an organic growth in the power sector data which needs a defined framework and process map for Operational Intelligence and Analysis.*

***Keywords:** Process Linking, Extensible Unified System, Information Technology, Data Platform, Design Engineering*

I. INTRODUCTION

Today's modern and advanced technology have numerous infrastructure, technologies and systems available to control, operate and design the power sector network. The network spreads across the generation, transmission, distribution, trading and associated up-streams and down-streams. Globally this is managed by independent models and systems for each sub-sector of the value chain. With smartgrid or Unified Data Platform all these data have to come on a common platform. The smartgrid will be instrumental in the integration of the smart-living concept by applying the smart energy systems to interconnect utilities with the end-users by means of a smart data infrastructure [1], [3], [4]. On one hand the volume, the variety, the variability, the velocity of heterogeneous data collected from these sensors have all added to the complexity; and on the other hand the availability of low cost storage and processing devices, has made it possible to process data at small time buckets for better analysis.

Manuscript published on 30 August 2019.
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We can capture time streaming data from devices for interpretation current system or to predict future events with higher accuracy. The grid can become more intelligent by processing and deriving information from the data. The dataflow in a modern power network has to be bi-directional, transferring information to and from secured and reliable data currently available on grid or in silos. The humongous amount of data being collected by various systems, be it on grid or in silos are discussed as a prelude to highlight the advantages of the "Process Map" for implementing a Unified Data Platform. The geographically large countries like India have a huge transmission network, large power generation and power consumer across the country. Most of them are developing and adopting new automation and technologies. The immediate implication is a mix of legacy and modern systems, which need to manage a huge data both structured and unstructured coming from various silos of the sector. At the same time the sector too needs to understand how to use this data for operational intelligence and analytics. As this data becomes huge and complex, the storage as well as the processing becomes crucial. The existing and legacy systems must be upgraded to handle the data storage and management. Smartgrid pose several bottlenecks that have been deeply studied and documented for integration of the infrastructure layer, information layer and the communication layer and The Smart Grid Architecture Model (SGAM) has been proposed by CEN-CENELEC-ETSI Smart Energy Grid Coordination Group [2]. The impediments now need to be addressed by country level power grids and other stakeholders after considering the layers suggested by SGAM [2]. Each node and link in the network produces huge amount of data within the system and applications in the silos. This paper studies the silos and proposes methods for Process Linking Extensible Unified System (plexus) that is required to integrate data from silos to a Unified Data Platform for operational intelligence and analysis of the power sector.

II. BUSINESS PROBLEM

Many of the data system are available in silos and perform tasks like performance analysis, energy management systems, remote monitoring, maintenance management, fault diagnostics, network and protection management, trading etc. This is a huge disadvantage as data in silos are produced by different system which makes it difficult to combine for unified management. The advanced networking, communication, protocols and systems allow complex systems to be integrated for operation, controlling, management and monitoring.

Retrieval Number: J98090881019/19©BEIESP
DOI: 10.35940/ijitee.J9809.0881019
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However this will require sectored intent, government push, technical support, environment and a process map to start with.

III. REVIEW OF LITERATURE

In the light of the above business problem, extensive literature review and research was carried out to identify the hardware, software and communication layers required for designing a process map for data unification on a common platform. 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 data gathered, this research proposes a process map for the data unification for 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.

A. Information Technology

Power sector applications now run on wide array of devices from handheld to large centralised servers. The advancement of mobile technology for enterprise mobility has provided enhanced capability, usability and affordability. The most visible advantage of the internet is the expansion of e-commerce making most products and services reach the end user. The reach has increased the impact on both business-to-business and business-to-consumer interaction. Availability of huge processing power enables effective and efficient processing of large chunk of information leading to operational efficiency, organizational intelligence and competitive advantages. This bi-directional exchange of data has altered the relationships of stakeholders by developing new products, services and business models. Information Technology is extensively used for integrated data management. Power sector extensively uses IT tools but mostly in silos. The unification of data will bring out new insights and business support system in the near future.

B. Lack of Unified Data Platform

The various stakeholders of power sector are generation, transmission, distribution and trading companies which use information technology for management of existing assets, inventories, operations and maintenance. Most of the operational losses are direct result of a lack of integration of processes. The challenge faced by the industry is a combination of legacy and modern technology added with inconsistent regulations and policies. The challenge is further increased due to difference in management and policy at state and center level. This in turn increases the pressure on each stakeholder to become cost effective and efficient in their boundary and silos. An alternative will be to bring the entire sector on a common platform and provide operational, regulatory and financial support at a higher level. The survival of each stakeholder depends on its delivery of quality product and services in cost effective manner to its consumers.

C. Challenges

The systems are available in silos and perform tasks like performance analysis, energy management systems, remote monitoring, maintenance management, fault diagnostics, network and protection management, trading etc. All these systems are data dependent and require communication of data between the independent systems. The analysis of data becomes very complex if carried out in the silos.
The challenge that the smart-grid and modern power plant management systems or energy management systems 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.

IV. RESEARCH OBJECTIVE

To develop a Process Map for addressing the identified gaps for a Unified Data Platform based on identified factors and tools for power generation, transmission, distribution and trading

V. PROCESS DESIGN METHODOLOGY

The process and sub-processes of the power sector is a well defined structure for both power and data flow. Central Electricity Regulatory Commission under its document File No. L-1/210/2016/CERC dated 15th May 2017 has been assigned the function to regulate the Grid Code and Grid Standard of the Electricity Act, 2003 to define the communication system which forms the backbone of the inter-state transmission of electricity and smooth operation of the power system. Section 8 of the document with heading "boundary of the communication system" states all stakeholders of the Indian power sector bound for the implementation of the communication system.

A. The stakeholders

1. NLDC
2. RLDCs
3. SLDCs (ISTS interconnection)
4. ISTS sub-stations of transmission licensee
5. ISGS, Central Generating Stations, Solar generation plants/ solar parks and wind generation pooling stations connected to ISTS as required
6. STU
7. Distribution Companies
8. State Generating Stations including renewable generators connected to State network

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9. Sub-stations of STU and State Transmission licensees

Though the policy initiates the process of implementation of a physical communication layer for the entire power sector, there are lots of financial, regulatory, hardware, software and data exchange protocol barriers which needs to be addressed for effective usage of data for operational intelligence. The barriers are mapped on the process map which becomes the blueprint for a Unified Data Platform.

B. Methodology

Process mapping is an integrated step for any Business Process Reengineering (BPR) which is structured, process-driven approach to improving the performance of an organization or system in areas such as cost, service, quality, efficiency and speed.

Contemporary BPR Methodologies

- Hammer and Champy Methodology
- Davenport methodology
- Process Reengineering Life Cycle (PRLC) Methodology
- Integrated BPR Methodology by Muthu, Whitman and Cheraghi
- Object-Oriented Business Engineering Methodology (OO-BEM) by Jacobson et al
- Accenture BPR Methodology
- McKinsey BPR Methodology

Some comparative of the steps for BPR methodology are given for reference below.

i. Hammer and Champy Methodology

1. Introduction into business reengineering
2. Identification of business processes
3. Selection of business processes:
4. Understanding the selected business processes
5. Redesign of the selected business processes
6. Implementation of redesigned business processes

ii. Davenport methodology

1. Visioning and goal setting
2. Identification of business processes
3. Understand and measure
4. Information technology
5. Process prototype
6. Implementation

iii. Process Reengineering Life Cycle (PRLC) Methodology

For this research we selected one of the more recent methodologies proposed for BPR, the Process Reengineering Life Cycle (PRLC) Methodology developed by Guha, et al. The new paradigm of Business Process Improvement seeks to achieve dramatic performance improvement by radically redesigning the organization processes. The PRLC used in this research is a comprehensive, six-stage methodology with guidelines for envisioning a reengineering project, getting started, diagnosing process pathologies, and redesigning, reorganizing, and measuring the newly configured process.

The six sequential stages (see figure-1) include:

- Envision new processes
- Initiate change
- Process diagnosis
- Process redesign
- Reconstruction
- Process monitoring

The PRLC then advocates for looping back to the beginning to diagnose processes that are again in need of change.

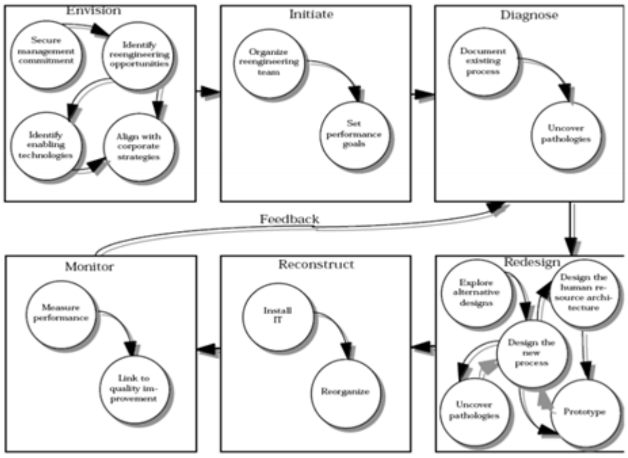

Figure-1 Six Stages of PRLC Methodology

C. Unified Modeling Language (UML) for development of Process Map

A picture is worth a thousand words. That's why Unified Modelling Language (UML) diagramming was created: to forge a common visual language in the complex world of process development that would also be understandable by business users and anyone who wants to understand a system. We used the inputs and outputs for developing the Process Map using Microsoft Visio Tool and UML.

A Process Linking Extensible Unified System (plexus) using the UML notations may be created to forge a common, semantically and syntactically rich visual modelling language for the architecture, design, and implementation of complex systems both structurally and behaviourally. UML has applications in software development, process flow, and design in manufacturing etc. It is analogous to the blueprints used in other fields, and consists of different types of diagrams. In the aggregate, UML diagrams describe the boundary, structure, and the behaviour of the system and the objects within it.

VI. PROCESS DESIGN STEPS

A. Step-1 Setting objectives

The first step of process mapping is setting the vital details or objectives to implement or improve a business process. The objectives should be measurable so that performance indicators to monitor how well the objectives align with the process. The objectives can be both quantitative and qualitative to encompass the expected design and lifecycle of the process.

B. Step-2 Process scope

The process scope must define the actors (users, organizations, externalities etc) who will use the process and their usage patterns, along with details of information, security levels, communication protocols and connectivity to external processes. User: the process owner? how the process is used? is the process automated or need human interactions?

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Information: business information that the process consumes and delivers? the expected output of the process?
Security: controls and security concerns of the process?
Communications and Connectivity: connections to external systems? How to access internal and external information? How to use applications?

C. Step-3 Process diagram

Using Microsoft Visio and United Modelling Language as tools, one can quickly draw out the process diagram; create the starting points, main steps, nodes and branches, decision points, end points and boundary conditions. While designing we need to keep in mind that though most business processes have a single start and end, however it is possible for multiple starts and ends. Parallel activities can use symmetric nodes to map out the parallel processes.

D. Step-4 Process details

This is the main process development level and requires addressing several steps and aspects.

Data: Define the inputs and outputs of each system or sub-system. Define data models, source, sink, storage, and data types.

Steps: Define steps for dataflow, data type, and descriptive name for each step.

Transitions: Define transitions of data, default path, branches, loops and descriptive labels.

Connectors: Attach connections with the steps, split steps where required. Connectors can be human activity, automated activity or mixed.

Actors: Define the actors, their connectivity, data flow.

Monitoring: Specify the key performance indicators (KPIs) to be monitored and their level in the overall process. KPIs will provide the data to monitor the objectives defined.

Error handling: Plan for exceptions, errors and unexpected behaviour of the system.

Maintainability: The process and the steps should be documented for maintenance and scalability where each element has descriptive labels.

E. Step-5 Process application design

At the completion of this step we will have a design which defines interaction of users with each process step.

F. Step-6 Testing

We validate the process map for errors or omissions in the definition and correct the flagged errors. We test the process with and without connectors, test independent actors, connectors and steps. Once the process design is free from local errors we might need to test the process in a real world system with a limited number of users or use cases.

G. Step-7 Deployment

When testing is complete, the process is ready to be deployed in real world system for entire user base and use cases.

H. Step-8 Continuous improvement

After deployment, the process is monitored using key performance indicators, to assess and improve to meet the objectives defined.

VII. ANALYSIS & INTERPRETATION

The process map for the Unified Data Framework is the base on which the system can be developed using models. The process map is based upon the real-life scenarios and organisation principles. The data must be designed and defined so that it can be used for classification, abstraction, association and aggregation as a whole or part of the larger structure. Analysing performance among power plants is difficult, as each power plant works within a unique context of resource, physical plant settings, and organizational goals. However, benchmarking provides indicators that allow us to examine individual circumstances and performances within groups of similarly-sized power plants. It must be suitable for storing and performing data analytics for the legacy as well as the future applications.

The diverse systems and network management is difficult as they are not coordinated due to disconnected systems and data management which leads to inconsistencies in records like duplication of information etc. It does not allow the analysis and diagnosis of the diverse activities to evaluate the sector as a whole. These disadvantages are primarily due to separate systems and data management which cannot be unified for management decisions.

A. The Process Map

The process map was based on the theoretical premise that the applications available in silos are based on the real-world power sector network. This made it possible to design a unified platform which supports the individual applications based on the sector specific structure.

The baseline analysis did not take into account the functionality of individual applications. The design philosophy was based on guidelines by National Institute of Standards and Technology, USA [6] as in figure-2. The basis

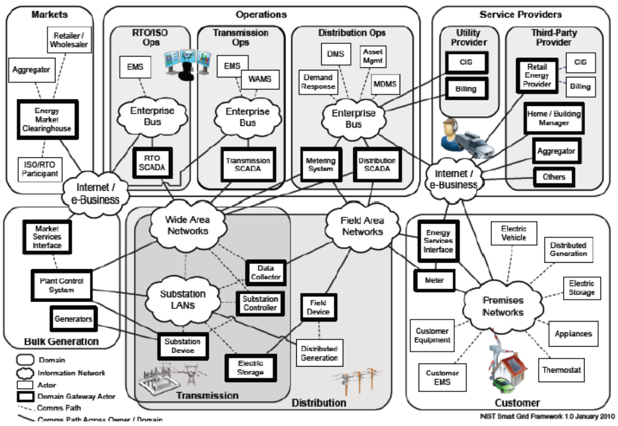

Figure-2 Conceptual Reference Diagram for Smart Grid Information Networks

of overall sector functionality was encompassed rather than the underlying sub sector and domains. A process built around the sector structure is more stable than based upon individual functionality. The process map is designed based upon the principles of thought process of the domain knowledge and experts.

B. Utilization of the Process Map for UDP

The unified framework integrates the various elements of the power sector and its activities. The process map is the base of the overall systems architecture.

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DOI: 10.35940/ijitee.J9809.0881019
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It defines the methods of data storage and data usage for different applications available in silos. This integrated system will have different and distributed databases. Therefore, the process map addresses the design of data layers, application layers and protocols for data usage etc.

C. Constructs of the Process Map for UDP

- The basic structure of the power sector can be represented as a set of nodes and links. The nodes are individual or a group of component of the entire system. A link connects and binds these nodes together for specific relationship.
- Cross-Platform Access to Data and Analytic - To seamlessly migrate from the legacy and existing applications and have cross-platform data and analytical engines to operate as a cohesive analytic environment. This transition should be transparent and the framework should combine the power of multiple analytic engines to address a business scenario.
- Include & distribute fast moving data through the ecosystems - The framework should provide an intelligent, self-reliant solution for inclusion and distribution of legacy and future data.
- Integrated hardware and application layer for speed and scale - For a powerful and ready-to-run enterprise framework the system should be easy to configure and optimize. An integrated hardware and application layer will have additional benefits like ease of manageability and reliability. The Platform should design keeping the existing infrastructure in mind and leverage current investments in technology and resources.
  Source: Teradata
- A Unified Data Platform is proposed for the unification of the platforms which will address the activities in the power sector defined by the individual elements and their interconnection.
- The effectiveness and accuracy of the management system should have closeness to the real-world network like the multilevel process map figure-3.

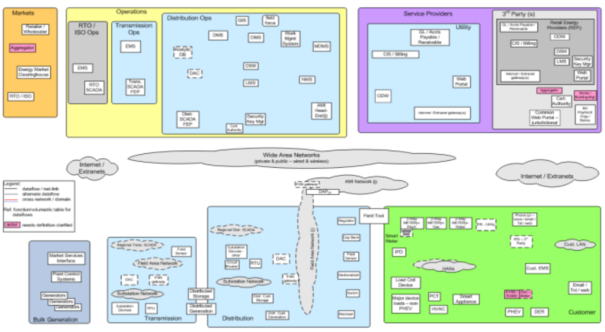

Figure-3 Multilevel Process Map

- The Platform should be scalable to handle the increasing customer base and numerous technologies which have increased the complexity of the energy management networks.
- A unified data Platform should improve the management of the independent applications as well as integrating the numerous technologies and infrastructure available in silos.
- Current system is customized for specific power application management and represents much specialized design and modeling. However, each of these applications in silos is based on the real-world network. It is therefore possible to build a unified data Platform which supports all data, protocols and systems to replicate the power domain structure.
- The unified platform should consider the increasing customer base on one side and installation of new and independent technologies which makes the system a large and complex model. In the yester years administrators and designers had an overview of the technical requirement for the design, scalability and management of the models. But today it is much difficult a task to manage the complex systems available even in silos and add to that the problem of the increasing data that needs to be processed.
- The Platform also needs to define interface for various data mining or data analysis methods like Pattern Matching, Classifications, Training and testing sets, Decision trees, Support Vector Machine (SVM), Clustering, Regression Analysis to name a few. The Platform must be defined so that the legacy systems and modern systems can co-exist.
- The Platform should be scalable and flexible to adapt and interface the future protocols and systems. The Platform should broadly classify data into generation data, transmission data, distribution data, consumer data and other relevant data.
- The Platform should define methodology for data centre to define intelligent data networks from all aspects of the system, be it technical, commercial, operational, maintenance, collection and other stake points to make the grid more intelligent, robust and smart.
- The Platform should allow users to define mechanism for filtering and cleaning the raw data to evaluate the data in necessary time buckets. These datasets will grow to hundreds of gigabytes the Platform needs to be designed with power and flexibility to meet all such requirements.
- The Platform should support numerous processing techniques like batch, stream, iterative processing. Thus, we require such a Platform to store this vast distributed data and to perform all these types of analysis.

D. Interfaces Required for Unified Data Platform

- Organizational Interfaces
- Technical Interfaces
- Financial Interfaces
- Application Interfaces
- Regulatory Interfaces
- Socio-economic and Organizational Interfaces
- Information Interfaces
- Hardware and Device Interfaces

The factors, constraints and interfaces for implementing a Unified Data Platform for Operational Intelligence and Analysis of the Power Sector was studied and published in author's paper [1].

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VIII. VALIDATION

The process map is designed on the outputs of defined power sector communication flow and the factors identified in this research. The map is not implemented and therefore the method of process walk-through was used to validate the process map defined in this objective.

The steps in walkthrough are shown in figure-4

1. The respondents with whom the process map was validated are independent from the experts who gave the data for designing the process
2. The researcher puts together the data collected from experts to design the process map
3. This is an iterative process to run the process map with the experts for accuracy of the flow
4. Checklist protocol is provided to validation group along with inputs, outputs and the process map
5. The final process map is then presented to a different set of experts independent from the original data providers for validating the map as per the design specifications

Figure-4 Process Map validation method

IX. CONCLUSION

The unified data platform designed inline to the process map can be used to extract the dynamic state of the power plant for numerous analysis like fault diagnosis, performance management, optimization systems, load forecasting. The 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 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 the process map but also need to upgrade or modify our existing systems in power sector and need policy level changes to ease the flow of data across the sector. Our study is on the information layer of power sector stakeholder for unification of data originating from the data source in silos. This research would provide a theoretical construct of how effectiveness of alternatives available should be explored and understood, before policy decision. The research also at the same time seeks to contribute to management practices. It is expected to enhance knowledge in emerging field of data unification or communication in the smart grid network in development of power sector. The objective is to design a process map in a structured, process-driven approach for improving the data exchange for operational intelligence and analysis of power sector in areas such as cost, service, quality, efficiency and speed etc. This radical change starts at the highest level of organization, and works down to the minute details to overhaul the system.

X. CONTRIBUTION TO LITERATURE

This complete redesign distinguishes BPR from other methodologies where incremental improvements are made through regular process improvements.

The term “reengineering” suggests that something has already been developed and is being re-developed. In most businesses, change to a pre-existing process happens relatively slowly and incrementally. Within the context of BPR however, the most modern tools are put to use in a way that uses them from the ground up. The fundamentals of already existing processes, ideas, and designs are rethought.

Davenport and Short suggest a more modest approach to BPR. They consider reengineering as a combination of the radical change approach and the discipline of continuous process improvement. According to them business process reengineering is "the analysis and design of workflows and processes within and between organisations". They recommend a structured and controlled approach to reengineering, which involves the selection of the most critical and important processes of the organisation, the analysis of their current performance and their redesign. Additionally, a number of articles from whitepapers, magazines, as well as books on BPR, or related concepts, have been used to support this work. A major support has come from the book Business Process Improvement, by Thomas H “Tom” Davenport.

Research study was done related to the applicability of the information technology tools and applications for newly designed work processes which led to keywords like

• Business Process Reengineering
• Business Process Improvement
• Business Reengineering
• Business Process Redesign

The research contributes towards the Business Process Improvement ("BPI") very popularly elaborated by Thomas H. Davenport.

XI. LIMITATION OF RESEARCH

Power sector is a complex network and addressing the directly and indirectly related factors and parameters will be a huge and time consuming task. The study had to be conducted with boundaries and limitations.

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1. The study was limited to India
2. The model might not be possible to be extrapolated to other geographies or nations

XII. FUTURE SCOPE OF RESEARCH

This research can be a building block which along with other industrial standards and research outcomes can be the guiding framework for a Unified Data Framework across the power sector.

1. The scholars can study the impact on independent data silos
2. The scholars can research on adaptability of the each systems in silo to the Unified Data Platform
3. Scholars can also study the role of regulatory, commercial and technical factors for data unification
4. The scholars can check the applicability on smartgrid

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2 21 February 2015 - Process Map of an "Unified Data Platform" for Operational Intelligence and Analysis of Power Sector in India, at University of Petroleum and Energy Studies

3 Paper submission at ICMI 2017 - "Unified Data Platform" for Operational Intelligence and Analysis of Power Sector, at University of Petroleum and Energy Studies

A. 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

XIV. AUTHORS PROFILE

First Author Profile

Pratik Ghosh, has an experience of 24+ years spanning across product and service organizations. He has worked 10 years with a leading German power engineering company with an extensive exposure on various responsibilities. He is Director at Plexus Infratech Private Limited, India.

He managed portfolios at an apex level for Project Cost Estimation, International Bidding, Feasibility Analysis, Commercial aspects of indigenous and import functions, negotiation, contracting, sourcing and delivery with deep understanding of Manufacturing, Service, Information Communication Technology, Infrastructure Services for Energy and Power, Telecom. He has International experience working in US, Germany, Turkey, Russia and UK.

Pratik is a PhD Scholar in Power Management at University of Petroleum and Energy Studies, Dehradun where his research area includes smart grid, ITES and IOT technologies, big data analytics, statistics and operational intelligence for the sector.

He holds a Bachelor of Engineering in Computer Science and Masters in Business Administration and has done senior management training programs from Indian Institute of Management, Indore

And Indian Institute of Technology, Delhi. He is a certified ISO 9001:2008 Auditor, CMMI level 5 Implementation Partner and certified Mathematical Modelling and Optimization System Designer.

An avid information technology professional with deep knowledge and experience in programming using languages Python, C# .Net, ASP .Net, C++, C, VB with database management of Oracle, MS-SQL, ADO .Net and experience in AI/ ML/ Neural Network for data analysis, statistical process management, system architecture design, Human-Computer Interaction.

He has designed and developed software solutions for performance optimization and statistical process control for large power plants and executed residential and utility scale solar plants. He has implemented Network Data Center for large scale utilities and has conducted technical and commercial advisory for projects in rural & urban area.

His career spans across various organizations and currently consultant for Essjay Ericsson and Artheon Electronics for power and telecom projects. He is director of Plexus Infratech Private Limited, BrioPlex Energies Services Private Limited. Prior to this he was with German power major Steag Energy Services Private Limited.

Research Papers

Two of his papers have been presented at Doctoral Colloquium In Management, Economics & Information Technology jointly organized by UPES, Dehradun and Gokhale Institute of Politics and Economics, Pune - Process Map of a "Unified Data Platform" for Operational Intelligence and Analysis of Power Sector in India and ICMI 2017 - "Unified Data Platform" for Operational Intelligence and Analysis of Power Sector.

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, International Journal of Recent Technology and Engineering (IJRTE)

ISSN: 2277-3878, Volume-8 Issue-2, July 2019

Retrieval Number: J98090881019/19©BEIESP
DOI: 10.35940/ijitee.J9809.0881019
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Second Author Profile

Dr. Ratna Banerjee, has over 16 years of rich experience and currently at UPES Dehradun as Assistant Professor teaching subjects like Mathematics, Business Mathematics, Business Statistics, Quantitative Techniques, Operations Research, Research Methodology, and Econometrics. An extraordinary teacher with excellent communication, presentation and interpersonal skills, bring in a combination of business expertise in applying various computational and optimization tools with academic rigor.

She holds a PhD in Applied Mathematics after her M.Sc.(Mathematics) and B. Sc. (Mathematics, Physics, Statistics). Certifications for computer application (SPSS, AMOS, Excel Modelling), Faculty Development Programme by Amity, Teaching and Writing Certificate and Machine Learning from IIMs.

She is life member of Analytical society of India, member of Indian Academicians and Researchers Association and Member of Ramanujan Society of Mathematics.

Book Publications

1. Mathematics-I (ISBN 978-93-81481-01-1) for BCA
2. Mathematics-II (ISBN 978-93-81514-15-3) for BCA
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Dr Kandpal holds Ph.D. in Management from Department of Management Studies, Kumaun University, Nainital. He is honours graduate in Commerce from University of Calcutta and did his MBA with dual specialization in Finance & Marketing. He is pursuing D Lit from Kumaun University Nainital on A Study of Social and Economic Implications of Financial Inclusion in Uttarakhand. He is Assistant Professor in Department of General Management, School of Business, University of Petroleum & Energy Studies, Dehradun. He has over 13 years of experience in Academics.

He has published 25 research papers in the areas of topics like Banking, Digitalization, Smart Cities, CSR, Corporate Governance and Infrastructure Finance in leading refereed and indexed Journals.

He has presented papers in National and International Seminars and Conferences on various topics in Institutes like IIM Ahmedabad, IIM Kozhikode, IIM Bangalore, IIM Indore, IIM Raipur and IIT Delhi to name a few. He has participated in the UGC Refresher Course organized by Academic Staff College Kumaun University, Nainital and FDPs in IIT Kharagpur and Banaras Hindu University.

His fields of Teaching and Research Interest are Financial Accounting, Management Accounting & Cost Accounting, Working Capital Management, Capital Market, Mutual Fund, Financial Management, Banking, Financial Inclusion and Financial Institutions. He is a member of All India Management Association Indian Accounting Association and Indian Commerce Association. He has published 4 books in the area of Accounting & Finance.

Research Paper: 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, International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-8 Issue-2, July 2019

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
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