Summer Internship Training Report

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DECLARATION

I hereby declare that the Industrial Training Report on "**Instrumented Pipeline Inspection Gauge Data Analysis & Visualization System**" at Research & Development Centre, Indian Oil Corporation Limited, Faridabad, Haryana is an authentic record of my own work as requirements of Minor Industrial Training during the period from June 03, 2024 to July 19, 2024 for the award of the degree of B.Tech. (Computer Science and Engineering), Manipal University Jaipur, Rajasthan, under the guidance of Mr. N.K. Malik, General Manager (Information Systems).

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Date: 19-07-2024

Certified that the above statement made by the student is correct to the best of ourknowledge and belief.

Examined by:

Ms. Kuljeet Kaur, Dy GM (IS)

CONTENTS

	Page No
Acknowledgments	4
Indian Oil Corporation Ltd & its R&D Centre at Faridabad	5-6
IS Department, Set-up and Configuration	7-14
Abstract	15-17
List Of Figures	18
INTRODUCTION	
Motivation & Scope of Work	20-21
INDUSTRIAL TRAINING	
Objectives	23
Tools & technology Used	24
Highlights of Training Exposure	25
Annexures	26-29
Learning Outcomes	30-31
Conclusion	32

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I would also like to extend my thanks to the entire team at **Indian Oil Corporation Ltd R&D Centre** for their warm welcome and for providing me with an enriching learning experience. The opportunity to work alongside such talented and dedicated professionals has not only broadened my perspective but has also inspired me to strive for excellence in my future endeavors.

I am indebted to all the esteemed personnel, especially **Mr. Aditya Raj (ISO)** and **Mr. Kamlesh Gupta (AM, L&D),** who graciously shared their time, expertise, and unwavering support with me throughout my internship.

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Indian Oil Corporation Limited

IndianOil is India's flagship Maharatna national oil company with business interests straddling the entire hydrocarbon value chain – from refining, pipeline transportation & marketing to exploration & production of crude oil & gas, petrochemicals, gas marketing, alternative energy sources and globalization of downstream operations.

The company's extensive marketing network encompasses over **58,000** customer touch-points, ensuring the widespread availability of petroleum fuels throughout the nation. Supported by a robust refining capacity of **70.05 MMTPA.**

Fueling the aspirations and dreams of approximately **30 million** Indians daily, IndianOil operates a vast network of over **34,000** fuel stations across India. Additionally, it's LPG brand, Indane, caters to more than **140 million** customers, making it a trusted and reliable choice for households nationwide.

It's extensive pipeline network, which spans over **15,000 kilometers**, making it one of the world's largest oil pipeline networks. These pipelines are designed to transport crude oil, petroleum products, and gas, ensuring a safe, efficient, and environment friendly mode of transportation.

With a remarkable throughput capacity of **94.56 million** metric tons per annum of oil and **21.69 million** metric standard cubic meters per day of gas, IndianOil's pipelines play a pivotal role in meeting the nation's energy demands. The company's expertise and experience in pipeline management have earned it recognition as a pioneer in oil pipelines in India.

IndianOil is also dedicated to renewable energy sources, with a solar PB capacity of around 70 MW, and a wind capacity of 168 MW, amounting to a total renewable capacity of nearly **240 MW.**

R&D Centre

IndianOil R&D Centre established in 1972, plays a key role in supporting GoI "**Atmanirbhar Bharat**" through indigenous technology development for energy security in India. Futuristic research is being carried out addressing the energy security and in alignment with the emerging energy scenario in core areas such as fuels & lubricants, refining technologies including catalysts, petrochemicals including polymers as well as sunrise areas like Nano technology, Solar, Bioenergy, Hydrogen, Fuel Cell, and energy storage. These R&D initiatives provide the much-needed support to various government initiatives towards sustainable and equitable availability of energy to all stake holders.

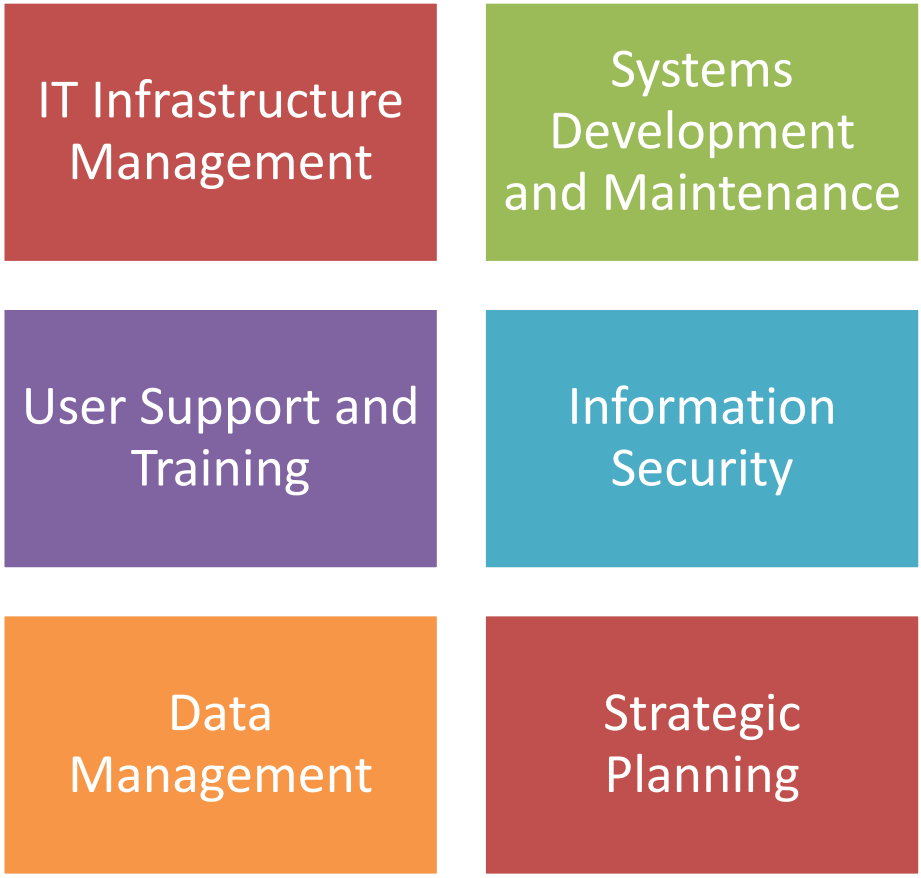
The Major Innovative and Development activities undertaken by R&D in various Research domains in line with "**Atmanirbhar Bharat**" for energy security, business diversification and energy transition are as follows:

Lubricants	Refining Technologies & Catalysts	Petrochemical & Polymers
Pipeline Maintenance & Inspection	Fuels & Additives	Alternate Energy
Bio-Energy	Nanotechnology	E-Mobility

Information Systems

The Information Systems (IS) Department is a functional unit within an organization responsible for managing and supporting the information technology (IT) infrastructure, systems, and services. It plays a critical role in the effective utilization and management of technology resources to meet the organization's strategic objectives and operational needs.

Responsibilities of an Information Systems Department:



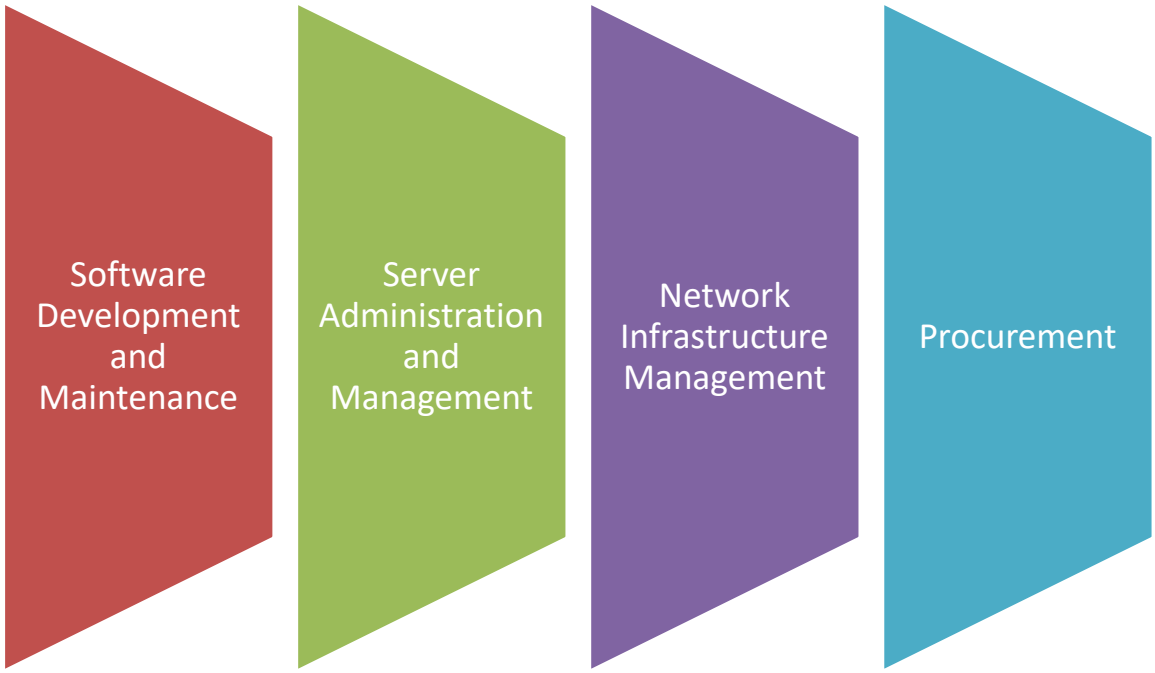
Components of an Information System:

- **Hardware**: The physical components of an information system, such as computers, printers, and scanners.
- **Software**: The programs that run on the hardware and control the flow of information.
- **Data**: The raw facts and figures that are processed by the information system.
- **People**: The users of the information system, who interact with the hardware, software, and data to produce information.

- **Processes**: The procedures and steps that are followed to collect, process, store, and distribute information.

The Information Systems (IS) Department at IOCL R&D Centre is a dynamic and highly skilled team of professionals dedicated to delivering exceptional technology solutions and support to the Organization. With a strong commitment to excellence, the department is equipped with state-of-the-art technology and tools to facilitate efficient and effective work processes.

Major Work:



Computer Networking:

A computer network comprises two or more computers that are connected either by cables (wired) or Wi-Fi (wireless)—with the purpose of transmitting, exchanging, or sharing data and resources.

The OSI Model:

The **open systems interconnection (OSI)** model is a conceptual model created by the International Organization for Standardization which enables diverse communication systems to communicate using standard protocols

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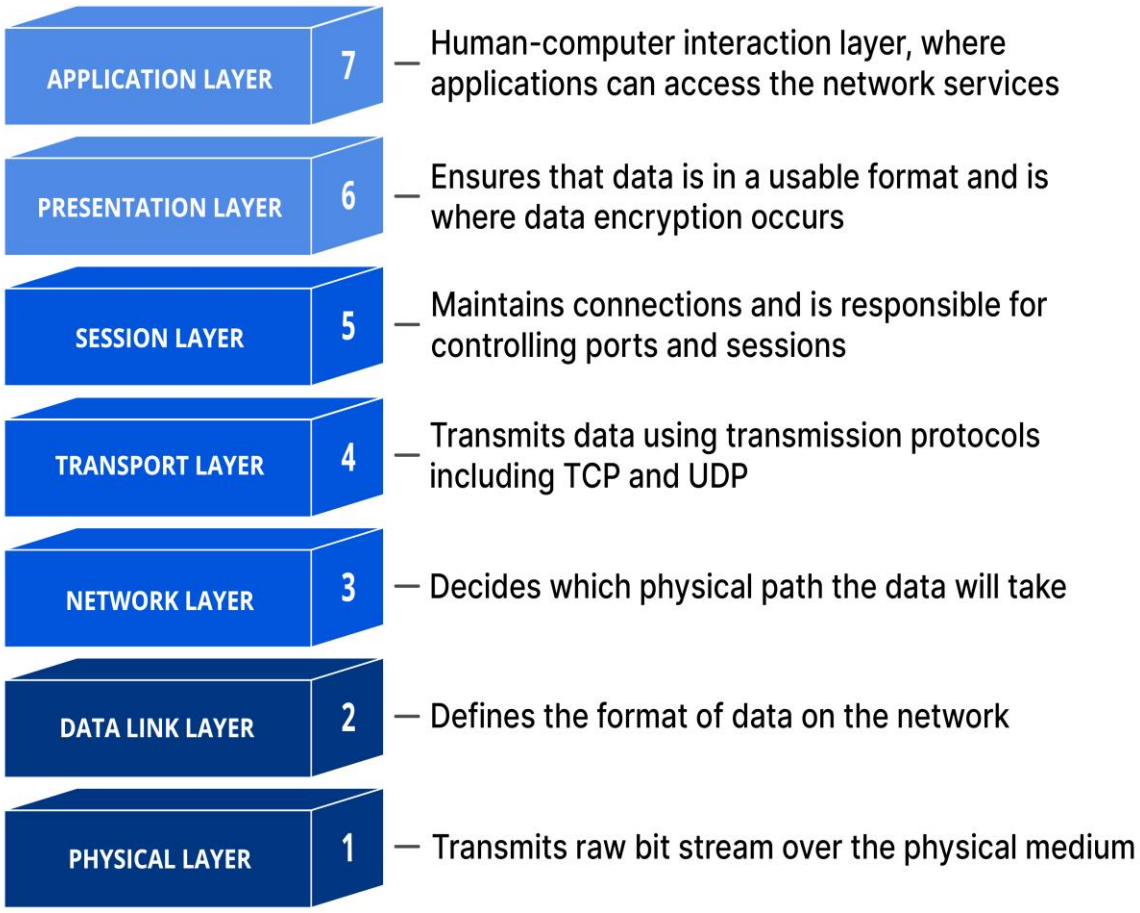
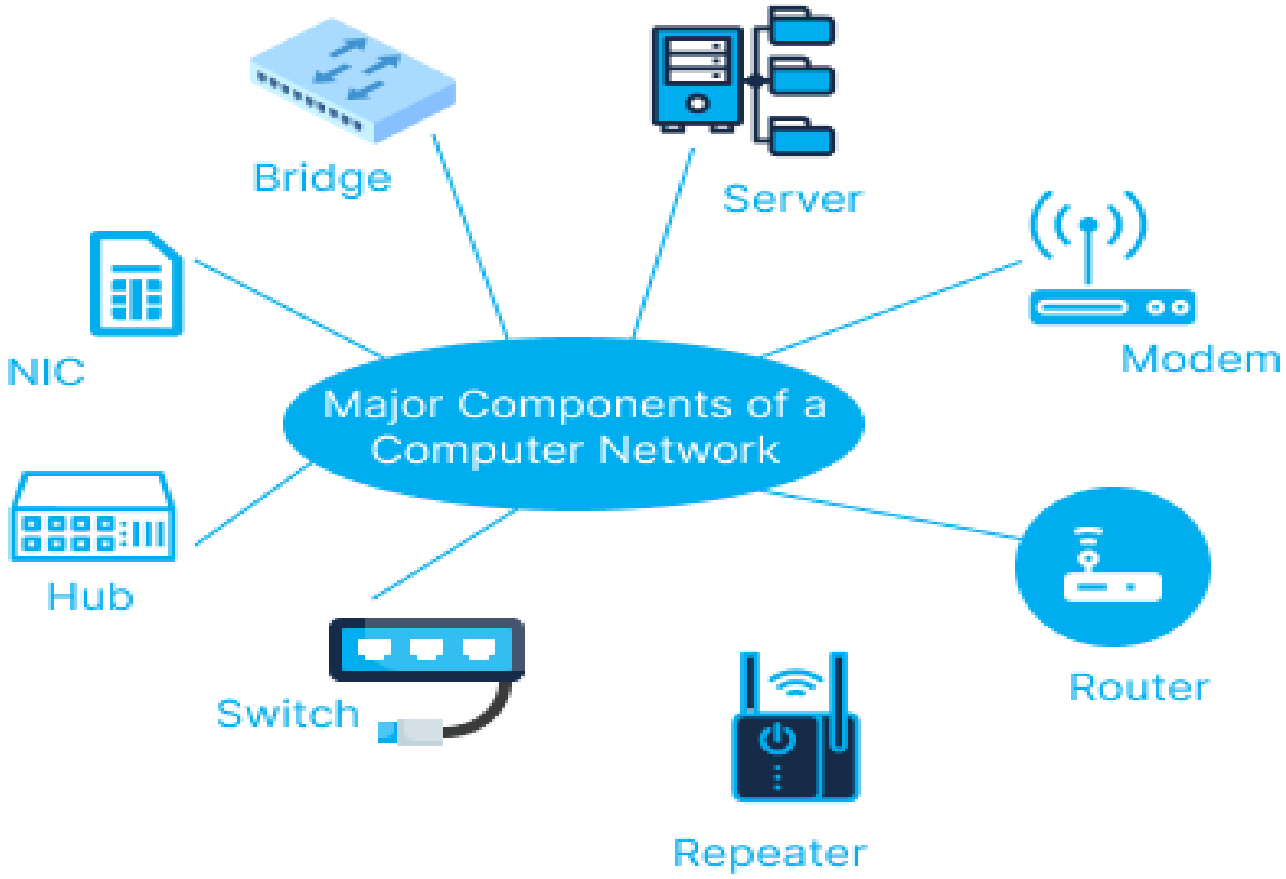
The **OSI** Model can be seen as a universal language for computer networking. It is based on the concept of splitting up a communication system into seven abstract layers, each one stacked upon the last.





Server Room:

A **server room** is a dedicated space within an organization's premises designed to house servers, networking equipment, and other critical IT infrastructure components. It serves as a centralized location for managing and operating the organization's computer systems and data storage.
It features specialized infrastructure and equipment to create optimal conditions for the servers.

R&D Centre has its own server room with a dedicated **UPS** room for power backup. It has **switch racks** and **server racks.** Some racks are **KVM racks** While other are controlled through the computer placed near the Server room.
The admin takes remote control from his office to make necessary operations.

he **Server room** is equipped with dedicated cooling systems, Temperature sensor and racks with ventilation holes to maintain a stable temperature.
Server room is **secured** physically. Access to the server room is restricted and is always under consistent monitoring.

Network Rack:

It is a metal frame chassis that holds, stacks, organizes, secures and protects various computer network and server hardware devices.

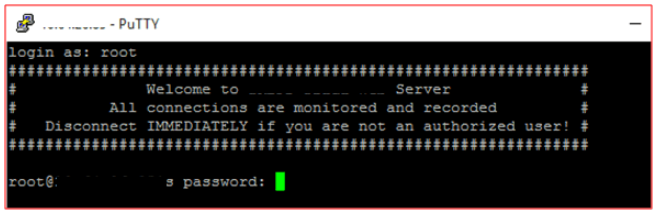
Components of a Switch rack:

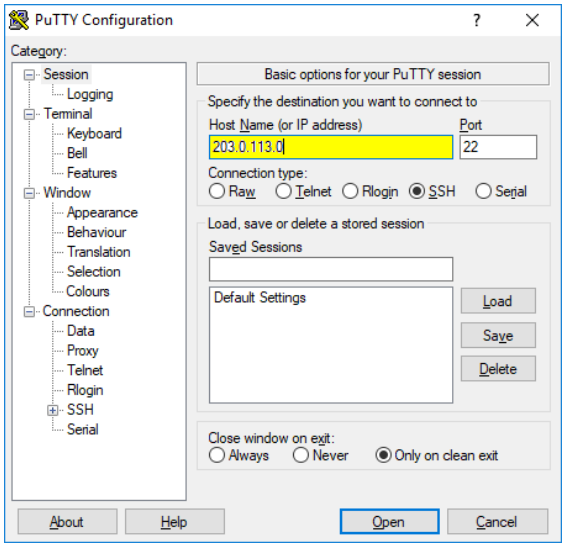
- **LIU (Light Interface Units):** used for routing, terminating, and managing optical cable terminations and can be wall-mounted or rack-mounted for ease of use.
- **Router:** a device that connects two or more packet-switched networks or subnetworks.
- **Switch:** A network switch connects devices within a network and forwards data packets to and from those devices**.** They can be labelled based on use case for example: RTDB switch, WIFI switch.
- **Firewall:** network security device that monitors incoming and outgoing network traffic and decides whether to allow or block specific traffic based on a defined set of security rules**.**
- **Power Distribution Units:** Distribute power to the network devices within the rack.
- **Monitoring and Management Tools.**
- **Cable Management.**

Connecting and configuring SWITCH:

Switches can be accessed and configured through the Command Line Interface (CLI). Accessing the CLI allows commands to be entered in a terminal-based window. To access the CLI you must use an SSH client. **PuTTY** is a standard SSH client.

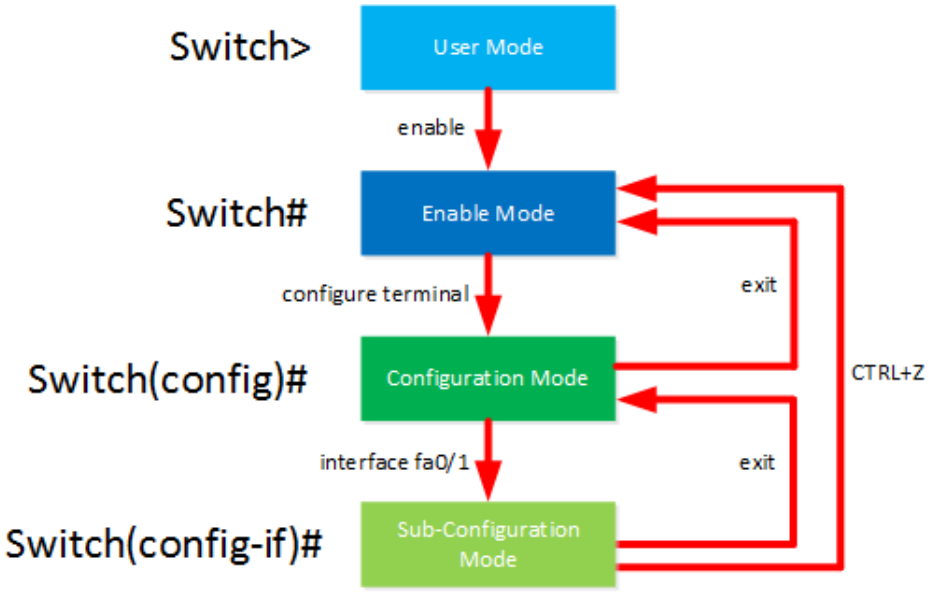
To connect to the **switch** (in a network) the IP-address of the switch should be entered. The connection type **SSH** should be selected and press open.





Upon entering the Login credentials, Opening Banner will appear containing Info.

Modes in CLI:



The Switch CLI uses **AAA** (Authentication, Authorization, and Accounting) models to implement passwords and other parameters.

- **Authentication** provides a way to identify a user, typically by having the user enter a valid username and valid password before access is granted.
- **Authorization** is the process of enforcing policies: determining what types of activities, resources, or services a user is permitted to access. After a user is authenticated, that user may be authorized for different types of access or activity.
- **Accounting** measures the resources a user consumes during access, which may include the amount of system time or the amount of data that a user has sent or received during a session. Accounting is carried out through the logging of session statistics and usage information.

The **Cisco IES program** is used to manage endpoints and make use of Network access control. The program has all the MAC addresses of endpoints connected and the admin can apply allow or ban from getting into the network.

VLAN:

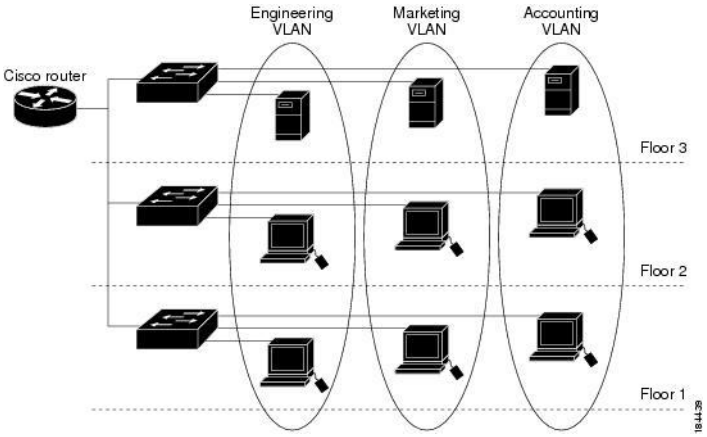
It is a group of end stations in a switched network that is **logically segmented** by function or application, without regard to the physical locations of the users. VLANs have the same attributes as physical LANs, but you can group end stations even if they are not physically located on the same LAN segment.
Any switch port can belong to a VLAN, and **unicast**, **broadcast**, and **multicast** packets are forwarded and flooded only to end stations in that VLAN. Each VLAN is considered as a logical network, and packets destined for stations that do not belong to the VLAN must be forwarded through a **router**.

Benefits:

- VLANs can be used to enforce security policies by limiting the number of stations that can be connected to a broadcast domain.
- VLANs can be used to improve network performance and security.

Drawback:

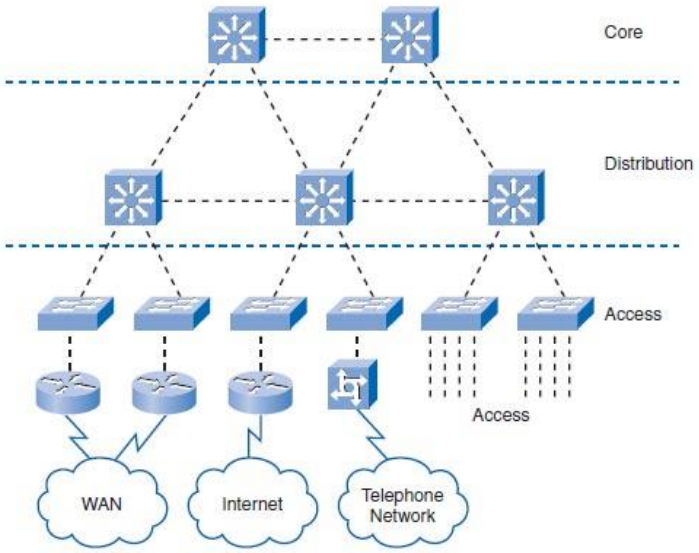
- Increased Complexity
- Negative Impact on Network performance



Network Distribution:

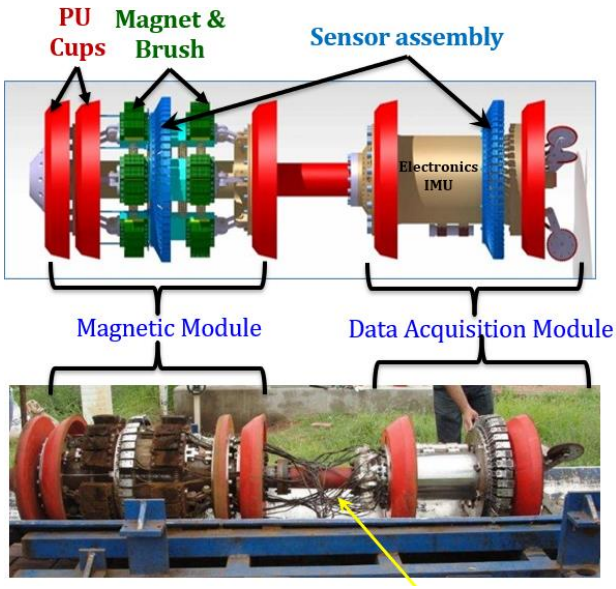
Network is Distributed at various levels in Large Organizations.

Core Switch: The primary transmission and routing of data signals take place at the core layer only.
Distribution Switch: These switches bridge the core layer and access layer. The main responsibility of these switches is to ensure the routing of data to correct devices in the access layer.
Access/Edge: These switches are the network switches that connect the access layer with the subnets.



Similar form of distribution of networks takes place at R&D Centre. From Internet Service Provider The net flow first goes through router -> firewall -> Core Switch -> Distribution Switches (Of various departments)-> Edge Switches -> End Pcs/ Clients.

ABSTRACT



The reliability and integrity of vast and spread-out pipeline networks of oil and gas industry needs periodic assessment. This can be done using Instrumented Pipeline Inspection Gauge (IPIG) to assure economical and environmentally safe transportation of petroleum products. Inline inspection (ILI) using Instrumented Pig (IPIG) is a mandatory testing for hydrocarbons transporting cross-country pipelines. IOCL R&D has developed Magnetic Flux Leakage (MFL) based IPIG tools "INDScan®" of several sizes and deployed the same for ILI of pipelines. Cumulative more than 16,000Km of inspection of various sizes of pipelines have been carried out successfully. The IPIG technology/tools have been developed in collaboration with 'BARC Mumbai' and is a shining example of "Make in India". IOCL IPIGs are available in different sizes (8" to 30" dia.). However, on demand any size of IPIG tools can be developed as IOCL R&D is equipped with state-of-the art facilities required for design, development, testing in pilot plants / laboratory etc. as per the customer need.

IPIG is non-intrusive and non-destructive inspection technology available only with select developed nations to assess the health & integrity of cross-country oil & gas transporting pipelines. Such an important task requires accurate graphing of the data acquired. The crucial task following data acquisition is to accurately depict the information using visualizations like line charts or heatmaps. These visualizations help pipeline operators identify trends, anomalies, and critical areas requiring maintenance, ensuring pipeline integrity and efficient product transportation.

External corrosion metal losses and additional attachment detected by the IPIG

Infrastructure for Design, Testing & Evaluation of IPIG

Elaborate design, testing and evaluation infrastructure are available for development of any size of IPIG, geometry and other PIGs. Testing facilities includes facility for negotiability check, leak tightness, vibration resistance, floating and movements in hydrocarbon, defect sensitivity and ease of launching / retrieving, in house designed Linear pull through rigs, hydrostatic test rig and wet test loops of various sizes are there to support.



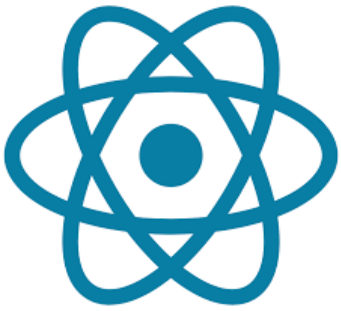
Infrastructure facilities for Testing & Evaluation of IPIG

Project - Instrumented Pipeline Inspection Gauge Data Analysis & Visualization System

A React framework was employed to develop a web-based visualization platform for IPIG data. This platform offers key functionalities of a grayscale heatmap, that provides a quick overview of potential issues, while separate line charts with zooming and hover interactions allow for in-depth analysis of data from each of the 369 IPIG sensors, facilitating quick identification of extremities and areas with lower flux values (indicating potential pipe thinning or product theft).

The developed web-based visualization system offers a user-friendly and accessible platform for pipeline operators to interact with and analyze IPIG data. This real-time access to insights empowers operators to make informed decisions regarding pipeline maintenance and repairs, enhancing pipeline safety and transportation efficiency.

The developed web-based visualization system, built with **React**, **Plotly.js**, and **Recharts**, offers a user-friendly and accessible platform for pipeline operators to analyze IPIG data in real time. Using **React** ensures efficient rendering and a responsive interface accessible from any device with a web browser, eliminating the need for separate applications and providing robust and dynamic data visualization, empowering operators to make informed decisions regarding pipeline maintenance and repairs, enhancing pipeline safety and transportation efficiency.



LIST OF FIGURES

Figure No	Figure Title	Page No
1	IPIG Visualization System	26
2	Grayscale Heatmap (240 sensors)	27
3	Line Chart (369 sensors)	28
4	Line Chart buttons	28
5	Heatmap buttons	28
6	Line chart before zoom	29
7	Line chart after zoom	29

Introduction

Motivation

The primary motivation for developing this web-based visualization system for analyzing IPIG data stems from the inefficiencies and challenges associated with the original graphing provisions. The previous system required extensive effort and time to load and render results, significantly hindering the workflow of pipeline operators.

A major issue was the need to install a Windows XP virtual machine on a Windows 11 system to render the graphs. This convoluted setup not only consumed valuable time but also complicated the process of data visualization, making it cumbersome and less accessible.

The new web-based system addresses these challenges by leveraging modern technologies such as React, Plotly.js, and Recharts. With this solution, charts and graphs can be rendered seamlessly on any device connected to the server network, eliminating the need for virtual machines, and ensuring quick, efficient, and accessible data visualization. This improvement allows pipeline operators to interact with and analyze IPIG data in real time, facilitating informed decision-making for pipeline maintenance and repairs, and enhancing pipeline safety and transportation efficiency.

Scope of the Work

The scope of this project encompasses the development and implementation of a web-based visualization system specifically designed for analyzing IPIG (In-line Pipeline Inspection Gauge) data. The project aims to streamline the data visualization process, making it more efficient and accessible for pipeline operators. The key components and activities within the scope of this work include: -

1. **Frontend Development:**
    - Developing a user-friendly interface using React 18 to enable interactive and responsive data visualization.
    - Integrating Plotly.js and Recharts for creating dynamic and detailed graphs and charts.

2. **Data Integration and Processing:**
    - Implementing methods to seamlessly import and process IPIG data, given knowledge of the type of IPIG used.

3. **Documentation and Training:**
    - Develop comprehensive documentation for system usage and maintenance; making it easier for operators, new and old, to use the website.

Industrial Training

Objectives

The primary objective of this project is to develop a web-based graph interaction system for analyzing IPIG data. This system aims to enhance the user experience of interacting and working with the data, while also providing a much faster and lighter application that can be used on systems of varying computing strengths. The specific objectives are as follows:

1. **Improved Data Visualization and Accessibility**

   Ensuring that pipeline operators can access and interact with data in real-time from any device with a web browser, eliminating the need for cumbersome setups.

2. **Easy-to-use website for Data Analysis and accurate monitory of pipelines**

   Enabled maintenance engineers to review past IPIG data, identify trends, and plan preventive maintenance activities effectively.

3. **Optimizing Data Processing and Performance**

   Minimizing time and effort spent on data analysis by optimizing web-based system performance. Enhanced efficiency by displaying large file data in paginated views and processing data in smaller, 5000 milliseconds chunks.

Tools & Technology Used

Our project leveraged a variety of modern tools and technologies to ensure efficient development and optimal performance. Below is a comprehensive list of the key components utilized:

1. **Development Environment**

- **Visual Studio Code**: Our primary integrated development environment (IDE) for coding and project management.
- **Windows 11 System (22H2)**: The operating system that served as our development platform.

2. **Web Technologies**

- **Web Browser**: Used for testing and debugging our web application.
- **HTML, CSS, and JavaScript**: Core web technologies for structuring content, styling, and adding interactivity.

3. **Frameworks and Libraries**

- **Next.js 14**: A React framework for building server-side rendered and statically generated web applications.
- **React 18**: A JavaScript library for building user interfaces, providing the latest features and improvements.
- **Recharts**: A composable charting library built on React components, used specifically for creating line charts.
- **Plotly.js**: A high-level, declarative charting library, employed for generating interactive heatmaps.

4. **Backend Technology**

- **Node.js**: A JavaScript runtime built on Chrome's V8 JavaScript engine, used for server-side scripting.

This combination of tools and technologies allowed us to create a robust, efficient, and user-friendly web application that meets modern development standards and user expectations.

Highlights of Training Exposure

Area and Scope

During this project, our team was exposed to a wide range of technologies and methodologies, enhancing our skills in several key areas:

1. **Web Development**
    - Front-end technologies: HTML5, CSS3, JavaScript
    - React ecosystem: React 18, Next.js 14
    - Data visualization: Recharts, Plotly.js
2. **Version Control and Collaboration**
    - Git for source code management
    - GitHub for collaborative development and code reviews
3. **Modern JavaScript**
    - ES6+ features and syntax
    - Asynchronous programming with Promises and async/await
4. **Responsive Design**
    - Mobile-first approach
    - CSS Grid and Flexbox for layout
5. **Performance Optimization**
    - Code splitting and lazy loading in Next.js
    - Image optimization techniques
6. **Backend Integration**
    - RESTful API design and consumption
    - Server-side rendering with Next.js

This exposure has significantly broadened our understanding of modern web development practices and tools, preparing us for future challenges in the field.

Annexures

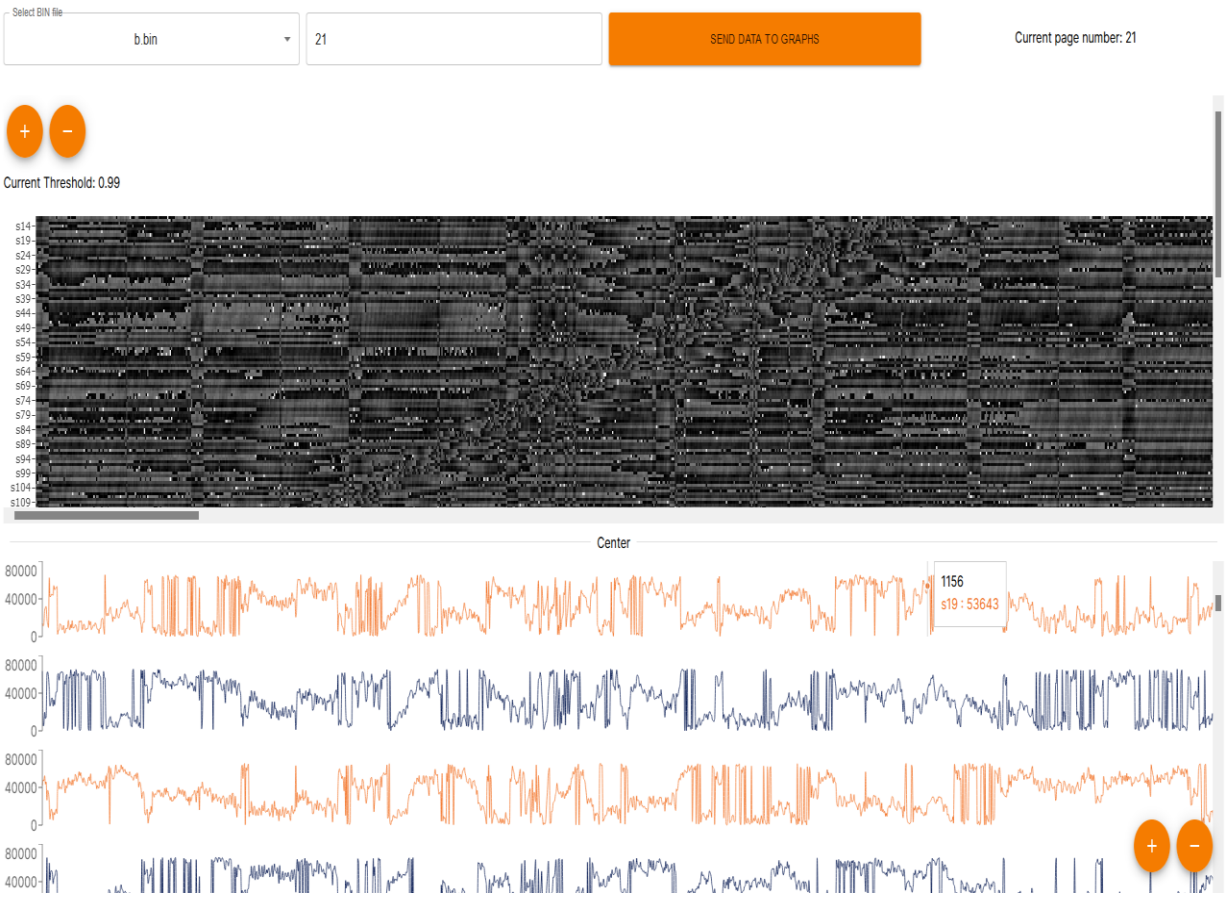


Figure 1- IPIG Visualization System

Description: -

- Toolbar at the top provides utilities to select the desired **.bin file** (binary file that stores all readings taken by the IPIG per second), **page number** at which data is to be read, and a button to render the heatmap and line chart for the selected bin file, at the user-inputted page number.

- Top-half of the webpage houses the **heatmap**, that uses the data from the first 240 sensors of the IPIG to provide a visual representation of the **thickness of pipe**, mapped on a grayscale color scheme. (*Higher the value, thinner the pipe*)

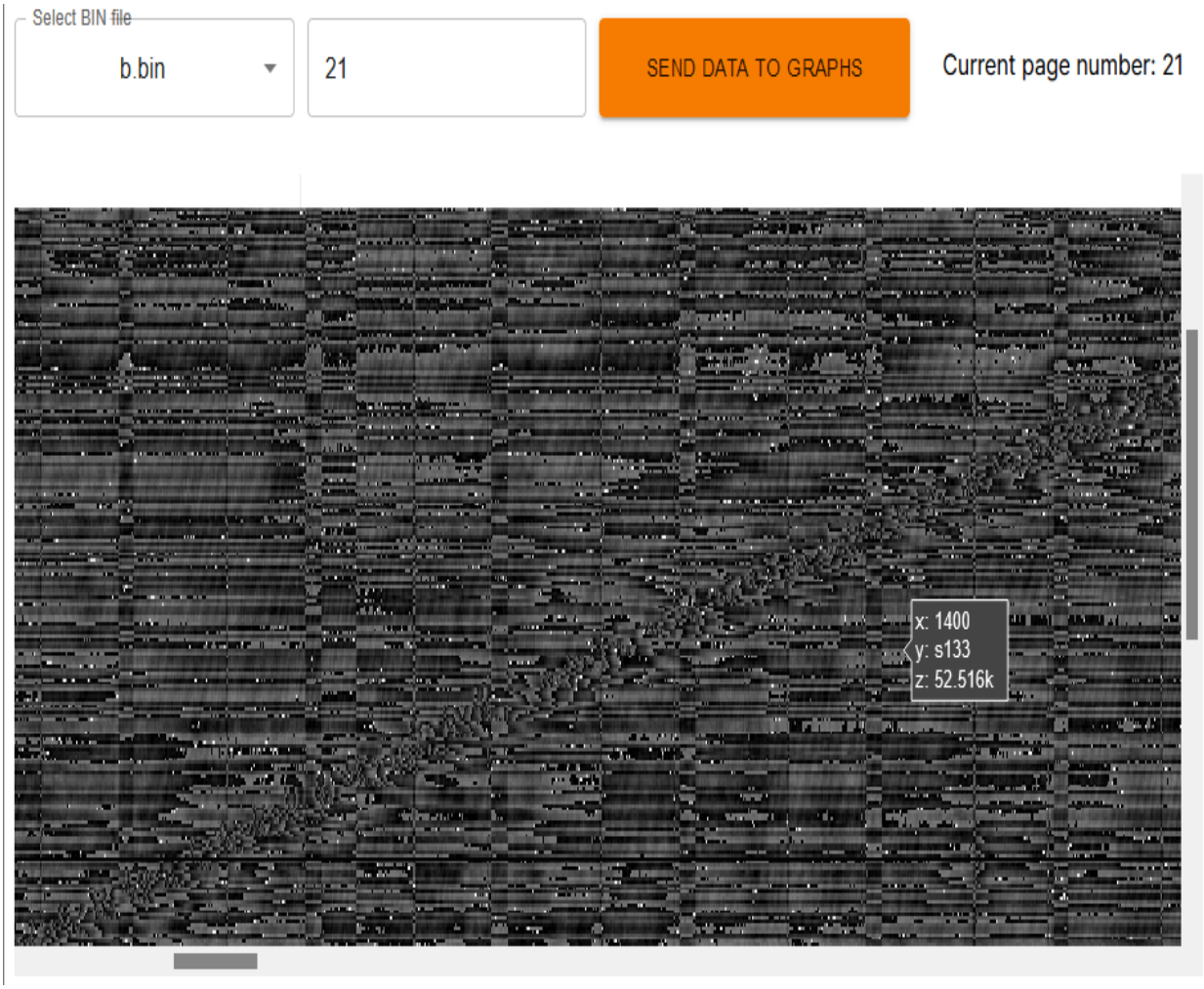


Figure 2 Grayscale Heatmap (240 sensors)

- Lower half of the webpage display the **line chart**, that displays a line chart plot of the data of all **369 sensors**

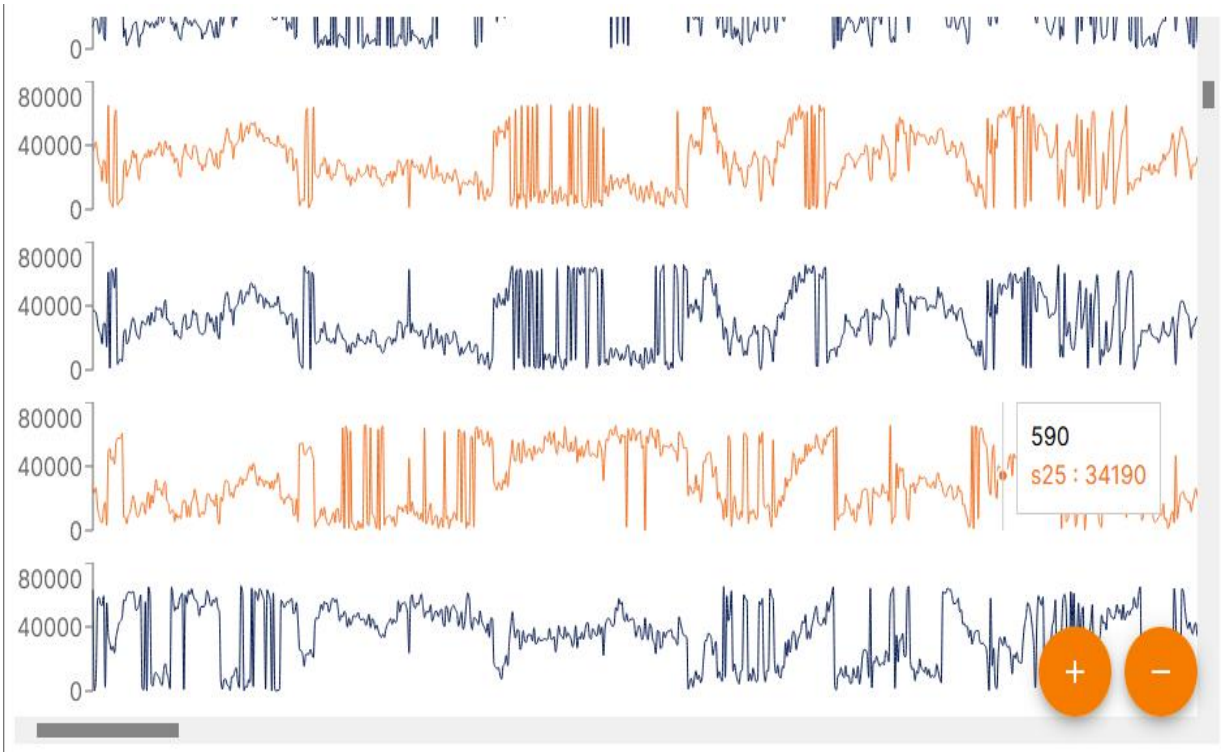


Figure 3 Line Chart (369 sensors)

- Attached buttons provide plot related functionality.

    - Heatmap buttons allow the operator to set the threshold, the values above which are anomalous/extremities/defects.

Figure 4 Heatmap buttons

Figure 5 Line Chart buttons

    - Line chart buttons enable horizontal zooming by extending the lines rightward, allowing for detailed inspection of specific sensor data points. (Page 11)

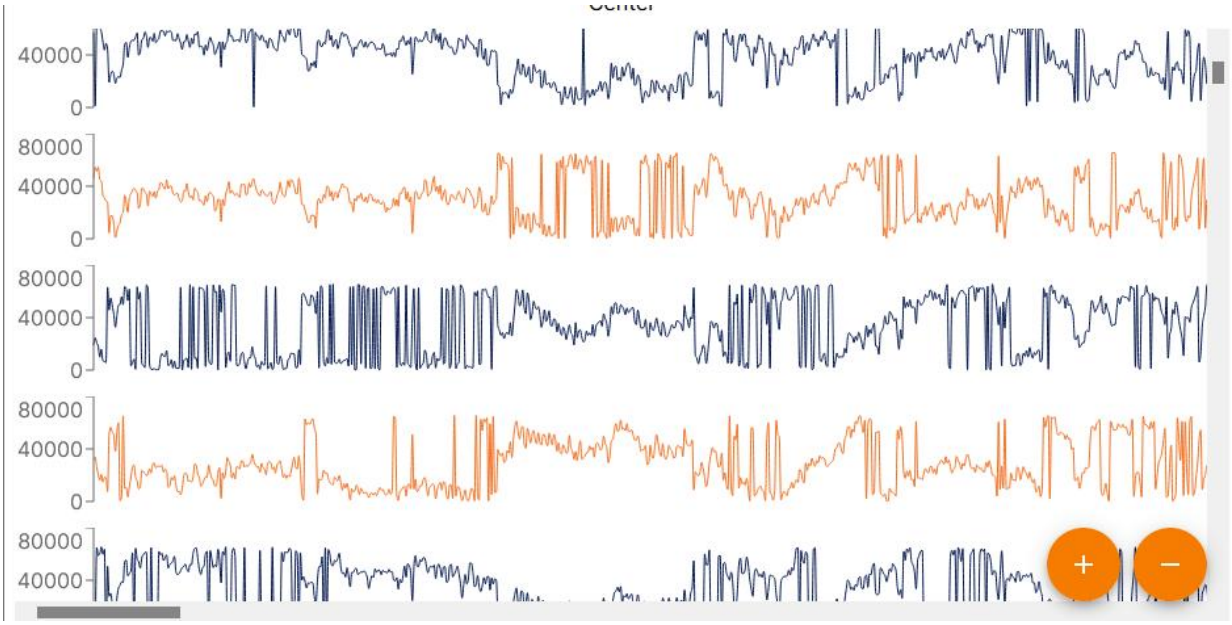


Figure 6 Line chart before zoom

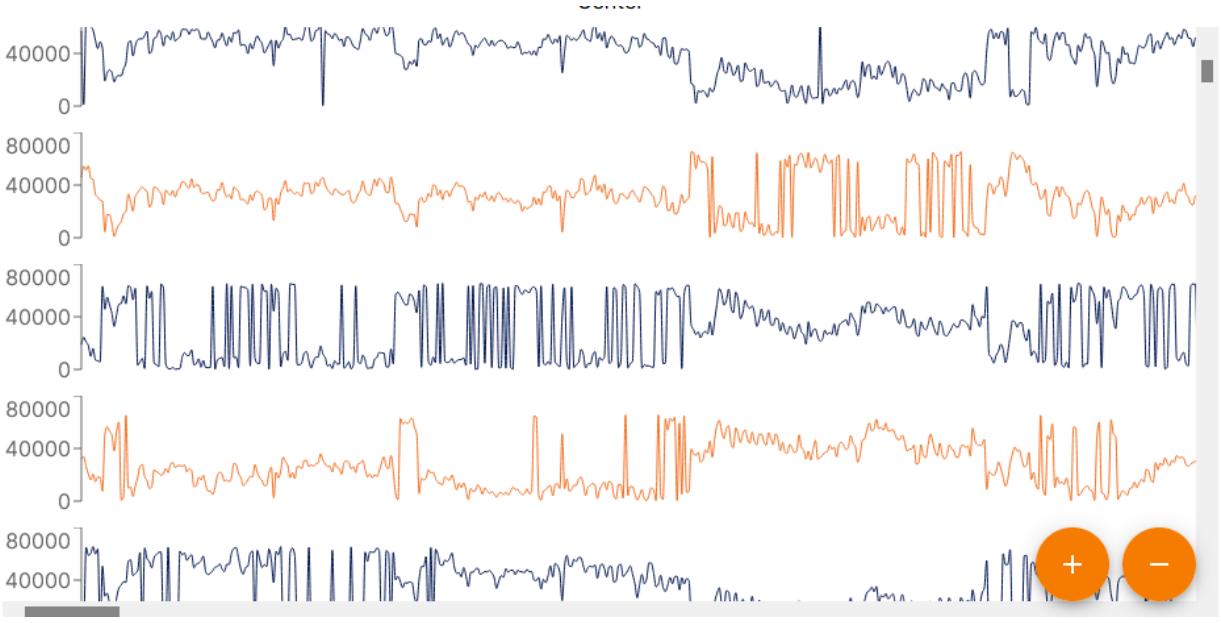


Figure 7 Line chart after zoom

Learning Outcomes

During my internship, I had the opportunity to immerse myself in various aspects of software development and industry practices, gaining valuable insights and expanding my skill set. key learning outcomes:

1. **Technical Skills Development:**
    - **Algorithm Design**: Acquired proficiency in designing efficient algorithms to solve complex problems, optimizing performance in data processing tasks such as parsing and validation.
    - **Frontend Development**: Mastered Next.js, Tailwind CSS, TypeScript, HTML, and CSS to create responsive and visually appealing user interfaces for web applications.
    - **Backend Development**: Utilized **Sequelize** for database management and efficient data handling, ensuring secure and scalable backend operations, learned managing databases and creating them using **MySQL**
    - **Data Visualization**: Implemented interactive visualizations using D3.js, enhancing data presentation and user engagement in analytical applications.
    - **Tools and Version Control**: Gained expertise in Git for version control and collaborated on projects using GitLab, adhering to industry best practices for code management and collaboration.

2. **Professional Skills and Practices:**
    - **Teamwork**: Collaborated effectively with colleagues, contributing to joint projects such as visualization components and system deployments, fostering a collaborative work environment.
    - **Professional Communication**: Engaged in clear and effective communication with team members and stakeholders, ensuring alignment on project goals and milestones.
    - **Industry Insights**: Developed a deep understanding of industry standards and practices through hands-on experience with real-world applications and challenges.
    - **Adaptability**: Learned to adapt quickly to new technologies and methodologies, responding to evolving project requirements and industry demands.

3. **Personal Growth**:
    - **Problem-Solving**: Enhanced problem-solving skills through tackling technical challenges and implementing innovative solutions in software development projects.
    - **Project Management**: Developed skills in project planning, execution, and delivery, prioritizing tasks effectively to meet deadlines and deliver high-quality solutions.
    - **Continuous Learning**: Cultivated a mindset of continuous learning and improvement, staying updated with emerging technologies and industry trends to drive personal and professional growth.

Conclusion

My internship at **IOCL R&D Centre** has been a transformative experience, immersing me deeply in software development and data analytics within a dynamic industrial setting. Throughout my tenure, I led the development of critical systems such as the Pipeline Inspection Gauge Data Analysis and Visualization System. These projects honed my skills in algorithm design and implementation using Next.js, React, Plotly.js, and TypeScript for efficient data management.

Collaborating closely with mentors and peers, I navigated the complexities of secure network configurations and efficient deployment practices. This experience not only sharpened my technical acumen but also underscored the importance of clear communication and teamwork in achieving project milestones. I am grateful for the guidance and support received from mentors and colleagues, whose insights have been invaluable in my professional growth.

Looking ahead, this internship has profoundly influenced my career trajectory, inspiring me to pursue further studies in computer science. I am eager to apply the knowledge and skills acquired at IOCL R&D Centre to drive innovation and contribute meaningfully to the field. I extend my heartfelt thanks to everyone at IOCL R&D Centre for this enriching opportunity and for preparing me to tackle future challenges in the evolving landscape of technology.