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Performance Evaluation of DWDM/MPLS/SDH/CWDM Equipment in PowerGrid's Telecom Network in North East India

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***Abstract*: This study evaluates the performance of DWDM, MPLS, SDH, and CWDM equipment deployed by Powergrid from three major vendors—Fiberhome, ZTE, and Tejas. Data was collected from Points of Presence (PoPs) in Guwahati, Shillong, and Itanagar. The performance was analyzed based on key factors such as battery bank health, air conditioner efficiency, PIU health, and DCPS health. Additionally, the study investigates fault rates, card failures, and SFP failures across different locations. The research methods include tests such as battery bank discharge analysis, air conditioner cooling efficiency, and PIU performance tests. The results highlight the direct relationship between supporting infrastructure and the performance of optical communication systems, offering recommendations for improving network reliability.**

***Keywords*: Battery Bank Discharge Test, Air Conditioner Cooling Efficiency, PIU, DCPS, DWDM, MPLS, SDH, CWDM, Powergrid, Network Performance.**

1. Introduction

The PowerGrid's telecommunication network is a vital part of India's communications infrastructure, leveraging a robust optical fiber communication system that spans across the country. It enables high-speed data transmission and supports mission-critical services for both enterprise and retail customers. The backbone of this infrastructure is built on advanced optical communication technologies such as Dense Wavelength Division Multiplexing (DWDM) [1], Multiprotocol Label Switching (MPLS) [2], Synchronous Digital Hierarchy (SDH) [3], and Coarse Wavelength Division Multiplexing (CWDM) [4]. These technologies enable efficient bandwidth utilization, faster transmission speeds, and scalability for growing data demands across multiple sectors.

The performance of DWDM [1], MPLS [2], SDH [3], and CWDM [4] systems is essential to ensuring seamless data transmission across PowerGrid's network, particularly given the geographical diversity and the increasing digital needs of urban and rural areas alike. However, these systems are heavily reliant on the health and stability of supporting infrastructure, which includes battery banks [5], air conditioning units [6], Power Interface Units (PIU) [7], and Direct Current Power Supplies (DCPS) [8]. These components collectively ensure that the communication equipment operates efficiently and remains resilient to power fluctuations, environmental conditions, and operational wear and tear.

Battery banks [5] serve as a critical backup power source in case of outages, ensuring that optical communication systems continue to function during disruptions. The operational health of battery banks significantly affects the uptime of these networks. Faulty or aging battery systems can lead to reduced power availability, contributing to network downtime and service disruptions. Regular maintenance and timely replacement of batteries are therefore essential to minimize service interruptions.

Air conditioning [6] units are crucial for maintaining the optimal operational temperature for telecommunication equipment. Excessive heat can degrade the performance of DWDM [1], MPLS [2], SDH [3], and CWDM [4] equipment, leading to increased fault rates and higher chances of component failure. In particular, components like SFP (Small Form-factor Pluggable) transceivers and communication cards are sensitive to heat, and their failure rates are directly linked to fluctuations in temperature within telecom shelters.

The Power Interface Unit (PIU) [7] is responsible for regulating and distributing power from the utility supply to telecom equipment. It ensures stable voltage levels, protecting the communication equipment from power surges and voltage drops. A well-maintained PIU [7] is critical for ensuring the longevity and reliability of the optical network. However, failures in PIU systems can result in sudden outages, severely affecting the entire network's performance.

The DCPS [8] plays a vital role in powering telecom equipment with stable direct current. Any instability or failure in the DCPS system can cause significant disruptions, as communication equipment requires a steady and clean power supply to function effectively. Sudden power outages or power spikes can lead to equipment damage and contribute to higher fault rates, particularly in sensitive systems like SDH [3] and DWDM [1] technologies.

This paper aims to assess the operational health of PowerGrid's optical communication systems by analysing key

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performance metrics, such as fault rates, card failures, and SFP failures. By examining the performance of equipment from various vendors (Fiber home, ZTE, and Tejas), this study seeks to gain insights into how different environmental and infrastructure factors impact the network's reliability across various geographic locations in India. The analysis will also consider factors such as the health of battery banks [5], air conditioning efficiency [6], and the performance of PIU [7] and DCPS [8] systems.

By categorizing and analysing these failures across different regions, the study aims to identify patterns and trends that can be used to improve overall system reliability. Understanding these patterns is critical for enhancing the resilience of PowerGrid's telecommunication network and minimizing operational inefficiencies that lead to downtime and financial losses. This study contributes to the growing body of knowledge on maintaining large-scale telecommunication networks, offering actionable recommendations for optimizing maintenance strategies, reducing fault occurrence, and improving customer satisfaction.

2. Research methods

A. Battery Bank Discharge Test

The battery bank health was measured using a controlled discharge test. Each battery was discharged at a fixed rate, and the time taken for the battery to reach the cutoff voltage was recorded. This test helps determine the energy backup capacity and the health of the battery. Different types of battery banks, ranging from 750 AH to 2250 AH, were tested for performance and durability.

The following bar chart illustrates the discharge time for different battery bank types. It can be observed that larger capacity batteries, such as the 2250 AH, provide significantly longer discharge times compared to smaller capacities.

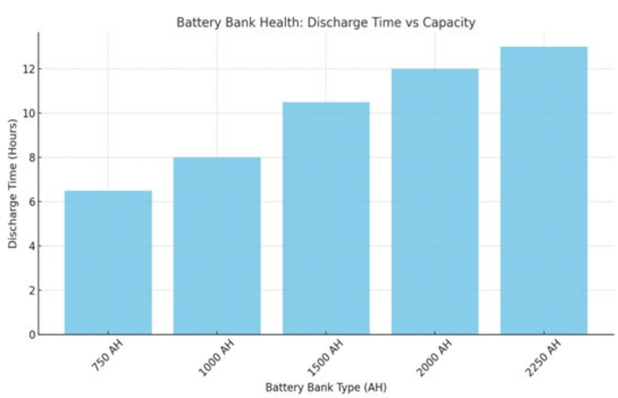

Fig. 1. Battery bank health: discharge time vs. capacity

B. Air Conditioner Cooling Efficiency Test

The cooling efficiency of air conditioners was measured by monitoring the temperature changes in the telecom shelter over time. Sensors were placed at different locations in the shelter to track the temperature distribution. Additionally, power consumption of the air conditioning units was recorded, and different tonnage levels were tested to determine cooling effectiveness.

The plot below illustrates the cooling capacity and energy consumption for air conditioning units of different tonnage levels. As expected, higher tonnage units provide greater cooling capacity, but also consume significantly more energy.

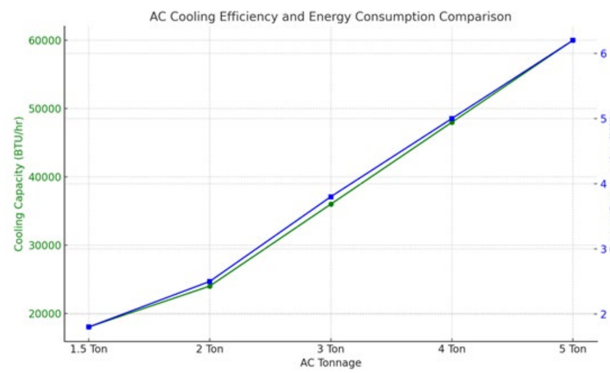

Fig. 2. AC Cooling efficiency and energy consumption comparison

C. The Analysis Focuses on the Following Performance Metrics

1) Fault Rates

This represents the percentage of equipment malfunctions over a given period. Fault rates were calculated for each vendor (Fiberhome, ZTE, and Tejas) across multiple Points of Presence (PoPs) in Guwahati, Shillong, and Itanagar. The goal was to identify patterns in fault occurrences and link them to the health of supporting infrastructure.

2) Card Failures

Card failures are critical because they can disrupt network operations and degrade the overall service quality. This analysis looked at the frequency of failures in various critical communication cards, such as line cards and controller cards.

3) SFP Failures

The failure rate of SFP (Small Form-factor Pluggable) transceivers was analysed to assess the impact of environmental factors such as temperature and power fluctuations. SFP failures can severely disrupt data transmission, making them a crucial factor in network stability.

4) Infrastructure Health

This component was evaluated through the performance of battery banks, air conditioning units, Diesel Generator (DG) sets, Direct Current Power Supply (DCPS), and Power Interface Units (PIU). Each infrastructure component was analysed for its operational health and impact on equipment performance.

Data from PowerGrid's Points of Presence (PoPs) in Guwahati, Shillong, and Itanagar were analysed to understand the regional impact on performance. Each location was assessed for equipment uptime, infrastructure health, and fault response times.

3. Results and Discussions

The results are presented in terms of fault rates, card failures, and SFP failures, alongside the health of supporting infrastructure. Equipment from three vendors (Fiberhome, ZTE, and Tejas) was evaluated. The key findings are summarized below:

A. Fault Rates

ZTE equipment exhibited the highest fault rates in Shillong, primarily due to poor air conditioning performance and degraded battery banks. Fiberhome equipment showed the lowest fault rates across all regions, with consistent performance in areas with stable infrastructure.

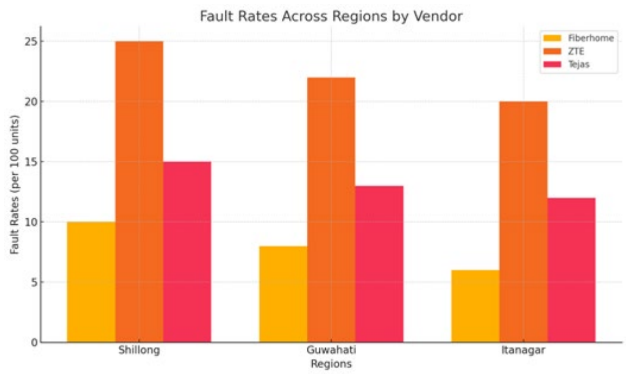

Fig. 3. Fault rates across regions by vendor

B. Card Failures

Card failures were more frequent in areas with unstable power supplies. DCPS instability in Guwahati contributed to higher card failure rates for ZTE equipment. Tejas equipment experienced fewer card failures, mainly in regions where the PIU health was optimal.

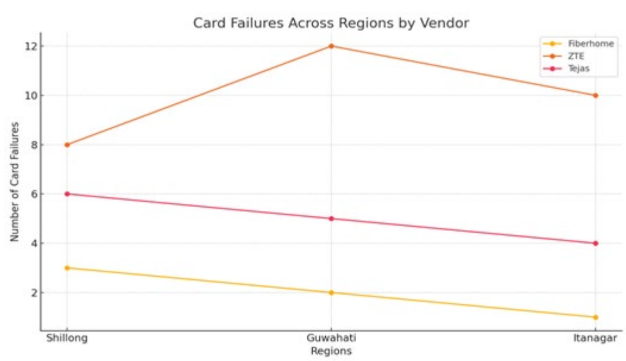

Fig. 4. Card failures across regions by vendor

C. SFP Failures

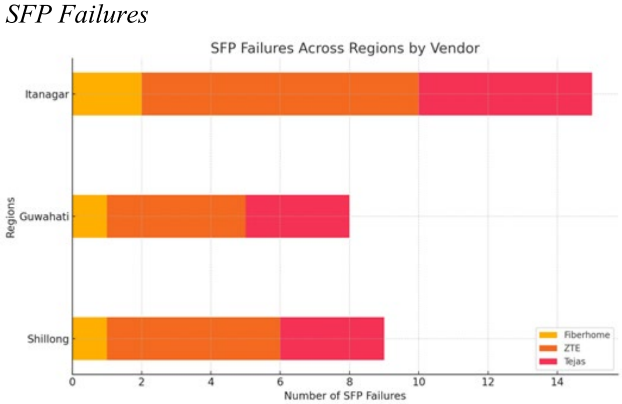

Fig. 5. SFP Failures across regions by vendor

SFP failures were highest in Itanagar, where PIU issues were observed. Inconsistent voltage regulation contributed to increased SFP malfunction rates. Regions with stable cooling systems and consistent power supply had significantly lower SFP failure rates.

D. Infrastructure Health

DG sets in Shillong showed the highest fuel consumption and the longest start-up times, impacting overall equipment performance. The poor condition of battery banks in the same region led to frequent network disruptions.

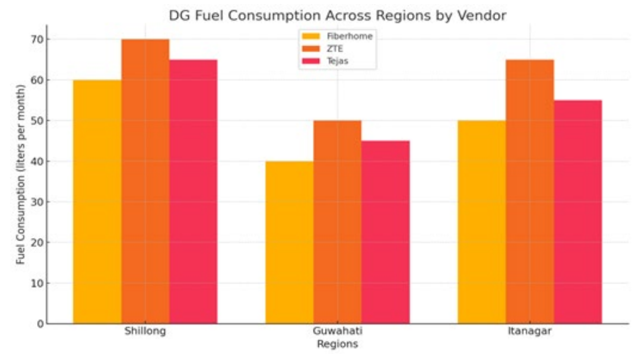

Fig. 6. S regions by vendor

Air conditioning units in Guwahati performed optimally, leading to better equipment health and lower fault rates.

The results highlight the critical role of supporting infrastructure in maintaining the reliability of optical communication systems. Poor infrastructure health, particularly in terms of battery banks and air conditioning units, was a major contributor to increased fault rates and equipment failures. For example, ZTE equipment in Shillong suffered from frequent malfunctions due to inadequate cooling and unstable power supply. Similarly, in Itanagar, issues with the PIU led to higher SFP failures. The findings suggest that improving the maintenance schedules for battery banks, conducting regular cooling system efficiency tests, and ensuring stable power supply from DCPS units can significantly reduce equipment faults. Implementing predictive maintenance techniques for DG sets can further enhance system reliability.

4. Conclusion

The study concludes that the operational health and reliability of PowerGrid's optical fiber network are heavily influenced by the performance of its supporting infrastructure components, including Diesel Generator (DG) sets, Direct Current Power Supply (DCPS), Power Interface Units (PIU), battery banks, and air conditioning systems. Regions with well-maintained infrastructure, such as stable power supplies and efficient cooling systems, experienced significantly lower fault rates, card failures, and SFP malfunctions, highlighting the importance of proactive maintenance. Fiberhome equipment demonstrated superior performance compared to ZTE and Tejas, particularly in areas with optimal infrastructure health. The analysis also revealed that regional variations, such as poor battery health and inefficient DG sets in Shillong and voltage instability in Itanagar, were major contributors to increased faults. To improve overall network resilience, it is recommended that PowerGrid focus on optimizing its maintenance schedules, implementing predictive maintenance for critical systems, and prioritizing infrastructure upgrades in regions with frequent equipment failures.

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