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A Study of Braking System Performance on Electric Multiple Unit (EMU) Class 83

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Abstract: The braking system's safety is critical for Electric Multiple Units (EMU). The development of brake systems in railway vehicles was caused by the high safety and comfort expectations under various condition. The main factors influencing brake system performance and function are braking force, vehicle mass and speed, stopping or braking distance, railway condition, and environmental factors. In this work, the types of brake systems such as emergency brakes, parking brakes and service brakes have been reviewed. The study is to analyze failures in the brake system and to propose the action taken to overcome the failure. In this context, data are collected based on the failure on brake system through three – year period from 2020 until 2022. Data collection technique via test run programme of set train and visual inspection. From the analysis, the problems of braking systems were caused by inadequate maintenance and outdated or obsolete braking technology. To reduce the failure of the braking system in trains, several measures can be implemented such as maintaining a strict maintenance schedule, adopting modern braking technology and installing monitoring systems to continuously assess the condition of the braking system during train operations. By addressing these underlying causes, the reliability and safety of train braking systems can be significantly improved.

Keywords: EMU, Brake System, Test Run Programme, Visual Inspection

1. Introduction

Train braking is a very complex operation that is unique to rail cars and has a significant impact on traffic safety. This complexity stems from the fact that several events of various sorts occur during braking - mechanical, thermal, pneumatic, electrical, and so on. The braking system is the ultimate safety element for EMU operation, and it is critical in controlling future increases in train speed [1].

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However, theoretical research focusing on finding braking system faults is limited. The majority of the existing work focuses on fault reasoning, qualitative analysis and failure types. The commonly used on-board problem diagnostic solutions for braking systems have significant limitations, depending mostly on simple threshold comparisons and specified operating processes [2]. It is worth mentioning that several mechanical components within the braking system are subjected to high loads for extended periods of time in complicated conditions, making incipient leakage failures caused by mechanical fatigue or wear fairly typical. Furthermore, the braking system may work in both ordinary braking mode, which includes changing degrees of braking, and emergency braking mode, with the distribution of brake force shifting depending on the mode of operation [3] [4]. Given these characteristics, there is an urgent need to develop early diagnostic systems capable of detecting leakage problems in the brake system across multiple operating modes.

Brake failures cannot be inspected or maintained while the system is running. Instead, these duties are only carried out during regular maintenance. The brake system's maintenance time follows its own separate exponential distribution. Furthermore, severe safety standards are incorporated throughout the system's design process, successfully assuring that the brake system remains free of faults while in operation. As a result, during normal system operation, a high level of dependability is ensured. Notably, when doing an overhaul, the emphasis is not on restoring individual components individually. Rather, the entire system is handled as a unified whole. So, the duration of the overhaul and the possibility of system state changes occurring throughout this procedure are not considered. Instead, the major aspect is assessing the repair effect on the system once the overhaul is accomplished. The researcher's focus in this article is on identify the failure rate of the braking system and to propose the corrective actions to rectify the failure of the braking system.

1.1 Type of Braking System

There are three types of brakes such as parking brake, emergency brake, and service brake. The parking brake is applied by spring. It is released by air charging and applied by discharging, which is a passive brake. Parking brake is applied only when the train be standstill to avoid coating. This brake can be released mechanically [5]. Next, emergency brake. It is includes driver emergency brake and passenger emergency brake. Emergency brake is irrecoverable and is interlocked with zero speed. This brake has anti – slide function. In addition, the following failures will trigger emergency brake such as train uncoupling and train over speed [6]. Therefore, the service brake. It is the brake mode for train in normal operation, with maximum service brake deceleration of 1.0 m/s^2. There are two types of service brakes which are regenerative brakes and pneumatic brakes. The regenerative brake detects when the train is travelling at speeds ranging from 20 to 120 km/h, whereas pneumatic brakes only detect speeds ranging from 0 to 2 km/h. During service brake, priority to apply regenerative brake and the rest brake force is supplied by pneumatic brake according to deceleration requirement when regenerative brake force is not sufficient. Service brake has anti – slide function and is recoverable brake mode [7] [8].

1.2 Principles of Braking System

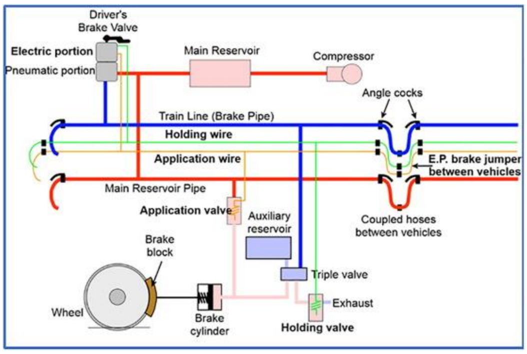


Figure 1: Schematic Diagram of Braking Control System

Figure 1 shows the schematic diagram of braking control system. It begins with the compressor at the motor car (MC), whether MC1 or MC2 supplied to the main reservoir. The main reservoir will be supplied the air until 10Bar. The auxiliary compressor will take over the role to ensure that there is sufficient air. The auxiliary compressor features a Governor that may turn off the air until the main reservoir tank is full. The compressed air is conveyed through the train by a brake pipe. The driver's brake valve has two types of brake controllers which are electronic brake and pneumatic brake. The electric element of the braking system uses different types of wire which are holding wire and application wire. Through this wire, there are valve involve it such as holding valve and application valve. This valve have exhausters. The vacuum in the brake pipes is formed then preserved by motor-driven exhausters. The exhausters have two speeds, namely high and low speeds. The high speed is converted into create a vacuum and so releasing the brake. The low speed is used for preserving the vacuum at the essential level in order to preserve brake release. Thus, the vacuum is protected against minor leaks in the brake pipes. The vacuum in the brake pipes is disallowed from exceeding its designated levels by relief valves.

The pneumatic brake supplied brake pipe from the driver’s brake valve to the brake cylinder through triple valve and auxiliary reservoir. Therefore, main reservoir pipe use the air from compressor to contact with brake cylinder for applying the braking system. When the brake is applied, the train recorder receives and interprets the messages. When the train operator applies the brakes, whether through a manual control or an automated system, a signal is sent to the brake system to activate the braking mechanism [9]. This signal triggers the release of compressed air or hydraulic pressure, depending on the type of brake system employed. As the signal reaches the brake system, it engages the control valves, which regulate the flow of air or hydraulic fluid. These valves direct the pressure to the individual brake units or cylinders located on each train car. The pressure is transmitted through a series of pipes or hoses, ensuring uniformity in the brake application across the entire train.

Upon receiving the pressure, the brake units apply force to the brake shoes or pads, which make contact with the train's wheels. This friction between the brake shoes and wheels generates the necessary resistance to slow down or stop the train. The effectiveness of this frictional force is crucial in achieving the desired deceleration and bringing the train to a controlled stop. Once the braking process is completed, the operator releases the brake command. This action signals the brake system to vent the air or release the hydraulic pressure, allowing the brake shoes or pads to separate from the wheels. This release enables the train to resume its movement smoothly [10] [11].

Throughout this flow of the brake system, various components such as valves, brake units, pipes, and hoses work in synchronization to ensure the proper application and release of brakes. Regular inspection, maintenance, and testing of these components are essential to guarantee their optimal performance and reliability [12]. In conclusion, the flow of the brake system in train operations involves the initiation, application, and release of brakes through a coordinated sequence of processes. This flow, facilitated by control valves, brake units, and frictional forces, plays a critical role in maintaining the safety, control, and efficiency of train movements.

2. Methodology

2.1 Method

Data performance of the braking system failure on EMU train was calculated through a test run schedule and a visual inspection. Test run will be conducted over a long or short distance to ensure that the train set is in good working condition. The frequency of train failures will increase due to the lengthy distance if the service is not in good condition. If abnormal damage occurs after the test run, a visual check will be performed. The analysis of braking system failures involves by identifying the failure, analysing the data, identifying root causes, identifying main effects, developing strategies to overcome failures, assessing feasibility and effectiveness, and implementing actions. The most suitable strategies are selected and prioritized, and a detailed plan is developed. Continuous monitoring and evaluation of the actions' performance and impact on reducing failures are conducted, with data collected on post-action outcomes. If initial actions fail, the process is repeated, and alternative strategies or expert advice may be sought to resolve persistent issues. This comprehensive approach helps identify root causes and implement targeted actions to improve system performance, safety, and reliability. After identifying the root cause, the next step is to develop effective strategies to address the issue. These include implementing different measures such as improving the monitoring systems, training programs, and component upgrades. The goal for this article were analyze the failure and propose the action taken to overcome the failure. All the work flow are based on the flowchart from Figure 2. To ensure that the research progressed well, the collected data was literately evaluated. Aside from the literature review, a conversation with the supervisor was held to have a better understanding of the project.

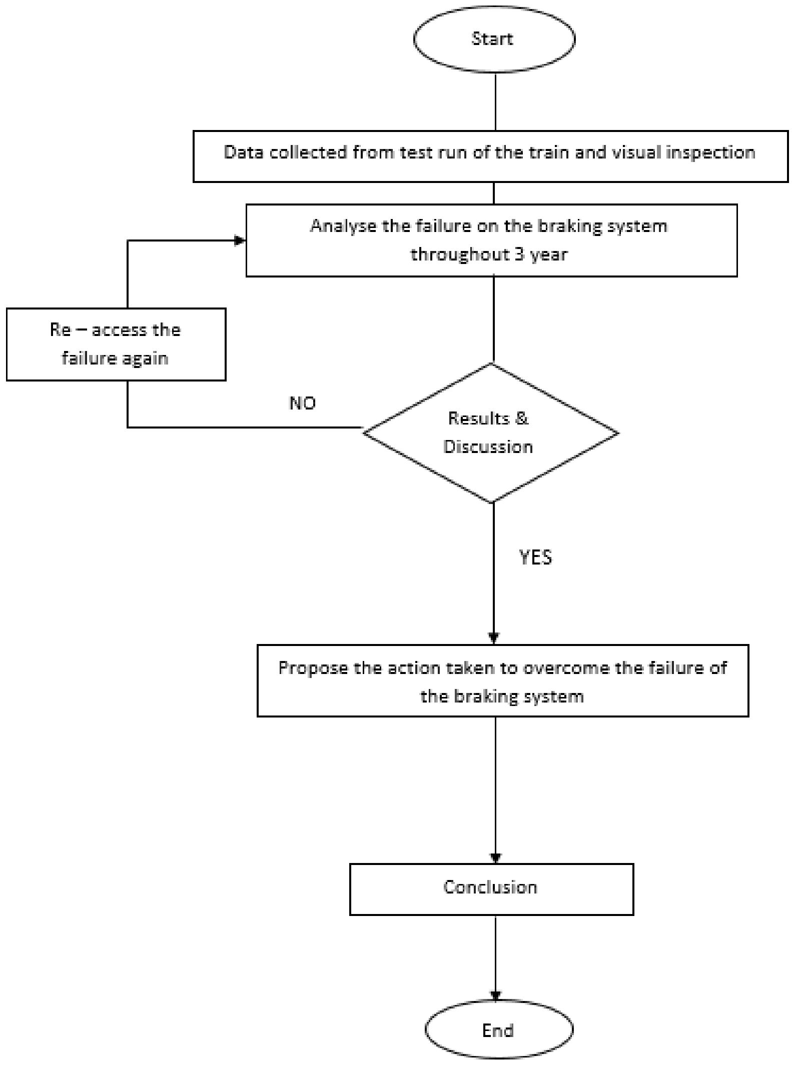


Figure 2: Flow Chart of the Project

2.2 Materials

The materials used include train-related tool sets such as wrenches, screwdrivers, pliers, hammers, multimeters, callipers, and others. These tools are used to dismantle and reassemble the components, remove fasteners, analysing electrical signals, measuring voltage and current, and retrieving fault codes, measure dimensions, tolerances, and clearances. All the tools are required during component overhauls. During the overhaul process, these tools guarantee that components are properly aligned and fit.

2.3 Equations

The air braking system is composed of a series of components. These components in the long-term use of the process will have varying degrees of failure, such as distributor valve failure, power brake control leakage, and brake control unit fail in the operation. The failure rate is calculated as follows in Equation 1.

$$Failure\ rate = \frac{times\ of\ failure}{total\ times} \times 100\% \qquad Eq. 1$$

In the process of urban rail transit train operation, the maintenance management system records the relevant fault date, fault description and processing results, and other information.

3. Results and Discussion

The results and discussion of the performance of the brake system in trains reveal significant findings and insights. The analysis of the brake system's performance highlights various aspects that contribute to its overall effectiveness and reliability. The study examines factors such as braking efficiency, response time, and the occurrence of failures or malfunctions. The discussion revolves around identifying the root causes of these failures and proposing suitable actions to address them. Preventive measures such as regular inspection and maintenance of brake components, as well as timely replacement of damaged or worn-out parts, are crucial to minimizing the occurrence of brake system failures. Additionally, the implementation of improved training programs for maintenance personnel to enhance their skills and knowledge can contribute to proactive troubleshooting and timely resolution of potential issues.

3.1 Difference between 3 years for brake system failure.

Figure 3 shows the percentage of braking system incidents from 2020 to 2022. In the years 2020 and 2021, the percentage of incidents in the braking system is 19% while in 2022, the percentage of incidents in the brake system is 62%. The number of incidents for the braking system in 2020 and 2021 is 4 whereas the amount is 13 in 2022. The study mainly focused on the EMU 83 class train since it includes a large number of sets, such as 14 sets from EMU 19 to EMU 40. The percentage of incidents was fell in 2020 and 2021 because of the Covid – 19 pandemic. After the pandemic Covid – 19 ended in 2022, the train's failure rate has grown due to train movement frequency. People are still concerned about viruses when utilizing public transit, such as trains, but in order to save time, energy and time, they choose to use the train to go to work.

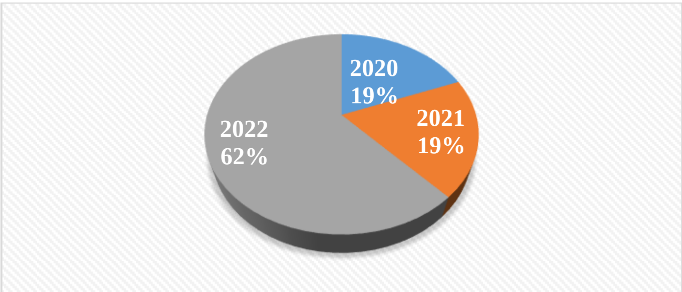


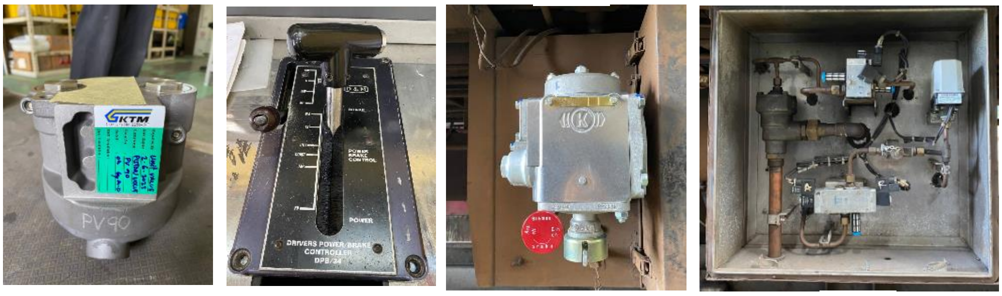
Figure 3: Percentage of the incident in brake system by years.

3.2 Root cause of failure in brake system

As listing in Table 1, Parking Brake Magnetic valve fault, brake binding, parking brake apply, MR drop or slating while running, brake frame heavy leaks, Power Brake Controller leaking, brake pipe fluctuated, MR late built up, Electrical Control Unit (ECU) fault, brake cylinder problem, Vacuum

Circuit Breaker fault, Converter Inverter fault, SV card in ECU fault and Auto Drop Magnetic valve fault are all potential causes of brake system failures. Failure of any of these components can have a serious impact on train operation. Figure 4 shows the component of the braking system that is constantly damaged.

(a) (b) (c) (d)



(e) (f) (g) (h)

Figure 4: Brake system component that is continually damaged

(a) – Brake Control Unit, (b) – Relay Load Valve, (c) – Brake Copper Pipe, (d) – Main Reservoir, (e) – Piston Valve, (f) – Power Brake Controller, (g) – Distributor Valve, (h) – Magnetic Box

Table 1: The root cause of brake system failure

Root cause of brake system failure	Frequency of failure	Percentage
Parking Brake Magnetic Valve fault	4	5%
Brake Binding	34	44%
Parking Brake Apply	2	3%
MR Drop during running	7	9%
Brake frame heavy leaks	4	5%
Power Brake Controller leaking	4	5%
Brake pipe fluctuated	8	10%
Main Reservoir late built up	2	3%
Electrical Control Unit fault	3	4%
Brake Cylinder problem	4	5%
Vacuum Circuit Breaker fault	1	1%
Converter Inverter fault	1	1%
SV Card fault	1	1%
Auto Drop Magnetic Valve fault	1	1%

Table 1 represents the root cause of braking system failure, as well as the frequency and percentage of failure. The higher of the percentage in braking system failure is 44%. The number of the train failure is 34. It is probable that the same train has experienced many failures, and that the problems are the result of EMU trains operating for a long period of time. It is possible that the component utilised has not been changed in a long time since the component is in good shape and the maintenance deadline has passed. It refers to the brake binding issue. Brake binding is a common occurrence for EMU trains. Brake binding occurs while releasing the brakes for a variety of reasons, the brakes will not release and the wheels will not rotate freely. Brake binding will severely harm the brake block and other components. The minimum thickness of the brake block 5mm. It must be changed if the value is less than the minimum range.

Brake binding affects the components such as the main reservoir, piston valve, brake pipe, distributor valve, brake cylinder, and master controller or power brake controller. Furthermore, the failure might occur when the electrical control unit and the brake control unit malfunctions. The train will run when the air in the main reservoir reaches 10Bar, the brake pipe has reached 5Bar, and the brake cylinder is activated. To detect brake binding, the MR value must be less than 7Bar, the BP gauge value must be less than 4 Bar, and the BC gauge will only detect air at 0.1 Bar. MR is commonly observable at air pressures ranging from 1 to 10Bar.

The major reason of the braking system failure, as indicated in Table 1, is the fluctuation of the brake pipe. The failure rate is 10%. The breakdown occurred on 8 trains. It is possible that the brake pipe has been fractured or is leaking as a result of an animal or human collision. The brake pipe works when the train brakes are released and the system is charged, the brake pipe delivers compressed air to each vehicle in the train. When the brakes are engaged, the auxiliary reservoir on each automobile delivers compressed air to the brake cylinder and is replenished when the brakes are removed.

Next, the root cause of the brake system failure is MR drop / slanting during running. The failure rate is 9% and the number of this type failure is 7. MR dropped takes place when the air pressure is less than 8 Bar. If MR does not have enough air, the train cannot operate. Furthermore, for the parking brake magnetic valve damage, brake frame weight leakage, power brake controller leakage, and brake cylinder difficulties all have the same percentage of brake failure, which is 5%, with a total frequency of failure of four trains. The larger percentage observed between them are brake cylinder problems. It is due to the sensitivity of this component that the failure occurred.

Automatic Train Protection, Vacuum Circuit Breaker, Converter and Inverter, SV card in ECU and Auto – Drop Magnetic Valve have the lowest percentage of failure in brake systems which is only 1%. This category has a lower failure rate since the components are not as sensitive. The component that has to be repaired would not require too long to fix. Because the cost of these component is so high, it is incredibly hard to break down. Accompanying discussions that further explain observations of the results are usually placed immediately below the results paragraph.

Figure 5 depicts the 14 sets of trains that must be tested. There are 4 braking system incidents in 2020. The trains involved are set 22 and set 32. The percentage of incidents in the service braking system of set EMU 22 is 25%, while 75% for set EMU 32. So, in order to conclude the data by percentage incidences of braking system failure, set 32 must be observed more closely. The mechanical and electrical components inside and outside of set EMU 32 have been changed to ensure zero failure. The problem with the brake system in Set 22 is Relay Load Valve (RLV). Therefore, the problem with set 32 due to a parking brake magnetic valve (PBMV) malfunction and parking brake cylinder leaking. This condition may result in brake binding. It happen in two condition such as unwanted brake application and no desired released. Unwanted brake application occurs when an air brake system uses mechanical components powered by pneumatic energy. Any issue with the air pressure or mechanical components will result in unexpected brake application throughout the run. For example, when braking, the brake cylinder may not be released under normal conditions, resulting in brake binding.

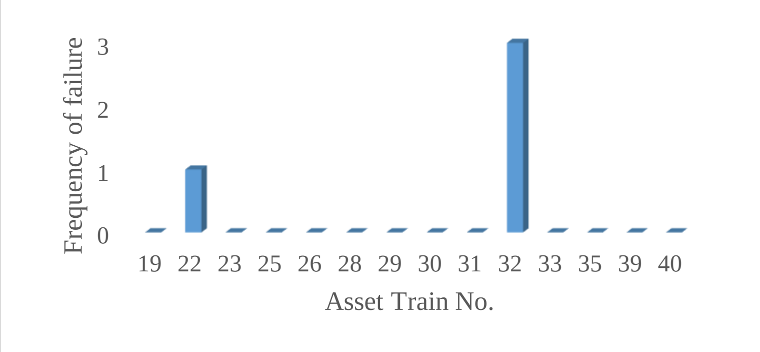


Figure 5: Incident in Service Brake System 2020 by Asset Train No.

Figure 6 illustrates the number of incidents in the service brake system for the year 2021. There are two types of failure which are major and minor failure. The observed failures are in the sets 30, 31, and 33. The percentage of the brake system failure for this three set EMU 30, 31, 33, has same which are 25%. For set 30, the diaphragm on the PBC is leaking, however for set 31, the Distributor valve, double check valve, and BP pipe line are all leaking, indicating a minor failure of the braking system. For the set 33, the major failure is the large bore stopped working due to a faulty Valve Head component. Therefore, the minor failure is the mechanical element of the PBC was discovered to be broken for example, the diaphragm was ripped, resulting in a leak in the PBC.

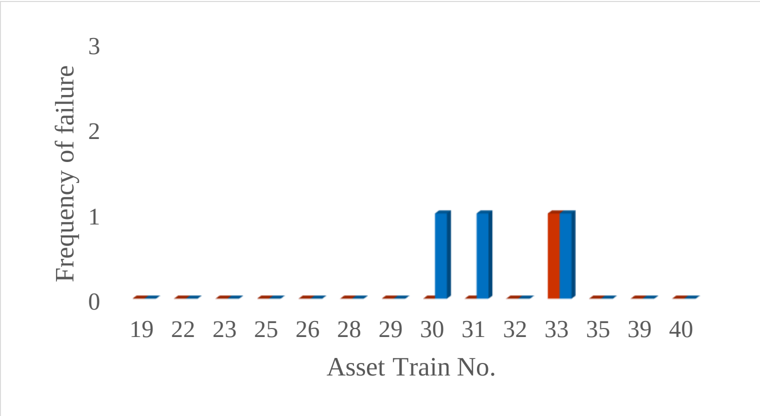


Figure 6: Incident in Service Brake System 2021 by Asset Train No.

Figure 7 shows that the percentage of braking system failure. This was the failure of the brake system for 14 sets of trains in a year. The average maintenance rate is increasing because of rising demand and a large amount of damage. After that, the percentage of the braking system failure in the set EMUs 19 and 31 is 17% whereas for another set EMU 24, 28, 29, 30, 32, 33, 35, 40 is 7%. As seen in the figure 6, it is illustrates that all of the incidents that have occurred are mild failures. The list of minor failures collected are SV card fault, PBC leaking, Pulse width Modulation (PWM), Distributor Valve and Double Check Valve, BP pressure switch, valve leakage, emergency valve blow and ATP system. This problem will be solved by an expert in troubleshooting. Every train that has a serious problem will require a long time to repair the damaged component, however a non-severe failure would take a short time. The set of trains EMU 19 and EMU 31 has a higher number of braking system incidents which is only 2. This is caused by brake binding.

Figure 7: Incident in Service Brake System 2022 by Asset Train No.

3.3 The Solution of the Braking System Failure

The braking system is crucial for the safe functioning of trains, and any fault or failure can endanger passengers and crew. To solve train braking system failures, there are several solutions, including emergency procedures, diagnosis and troubleshooting, component repair or replacement, and routine maintenance and inspection.

First, inform the crew of the brake system failure, ensuring clear communication and action. Activate emergency brakes to bring the train to a controlled stop, limiting braking power loss and preventing further acceleration or accidents. Establish clear communication between the driver and the train control center, and follow evacuation protocols if necessary.

The railway industry has implemented various solutions to address and minimize braking system breakdowns, such as redundancy systems, regular monitoring and repair, and routine inspections and testing. Technological advancements in braking systems have significantly improved safety and dependability. Emergency braking systems are equipped in cases of failure, providing an extra layer of security. Proper train operator, conductor, and maintenance crew training is essential for efficiently addressing braking system problems.

However, no system is completely fail-proof, so the emphasis remains on continuous development and installation of steps to increase safety, dependability, and reaction capabilities in case of train brake system problems. The railway industry aims for maximum safety and efficiency in train operations by combining these complete solutions.

4. Conclusion

To sum up, the two objectives of analyzing the failure and purpose the action taken to overcome the failure in brake system has been achieved. A thorough review on performance for braking control system on Electric Multiple Unit has been investigate. Also, the principles and technique of brake system using schematic diagram has been presented. In conclusion, the braking system is critical for managing speed, halting the train, and ensuring passenger safety. The ability of the brake system to identify any fault that may have occurred, even if the system has automatically compensated for it, is critical for end users and maintenance personnel. Failure will have an influence on the outcome, which is that the brake will be inefficient. By addressing the causes of brake system failures and adopting suitable solutions, the performance of the braking system in EMU trains may be improved, resulting in safer rides, higher operational efficiency, and increased passenger satisfaction.

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