सत्यमेव जयते

GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

Handbook on
Predictive Maintenance practices for Signalling Assets



End User: Signal Engineers of Indian Railways

CAMTECH/S/PROJ/2020-21/SP3/1.0
August 2020

अअमा सं RDS रेल अमृत Transforming Railways

EXCELLENCE IN MAINTENANCE

Indian Railways
Centre for Advanced Maintenance Technology

INDIAN RAILWAYS
Centre for Advanced Maintenance Technology
Maharajpur, Gwalior (M.P.) Pin Code – 474 005

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Predictive Maintenance practices for
Signalling Assets

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Foreword

Railway Signal Interlocking system comprises of various electromechanical assets such as Electric point machine, Electric Lifting Barrier as well as sophisticated electronic assets such as LED Signal, axle counter etc. which are responsible for safe operation of trains.

Failure of any asset causes train detention and the process for restoring the failure may be time consuming if root cause is not known. For safety and efficiency in train operation, the availability of signalling system is to be ensured. There are various factors which pose big challenge to this objective for S&T department such as large number and variety of assets to maintain, complex circuitry, exposure to all type of weather, insufficient skilled personnel, dependency on other departments and unpredictable faults.

To monitor the health of an equipment continuously and attend it before reaching failure state is not possible through routine periodical maintenance. Predictive maintenance based on condition monitoring of signalling assets can be of great help in prevention and rectification of failures.

In continuing its efforts in documentation and upgradation of information, CAMTECH has prepared this handbook for S&T personnel to get them acquainted with the upcoming technologies being developed by RDSO and different vendors for predictive maintenance of signalling assets.

CAMTECH Gwalior

Jitendra Singh
Principal Executive Director

Preface

Railway Signalling system plays a vital role in the safe movement of trains and the efficiency of any Signalling system depends upon the availability of associated equipments. Although corrective maintenance and periodical maintenance can prevent failures up to some extent, these are not sufficient for flawless performance of the asset as maintainer is not pre-warned regarding any abrupt fault developing between two consecutive visits. Hence if condition of all the equipments is monitored continuously by any suitable means, predictive action can be taken thereby avoiding undue delays in restoration and will help in reducing Mean Time to Repair (MTTR).

CAMTECH has prepared this handbook to help S&T personnel in understanding the concept of predictive maintenance through condition monitoring of signalling assets. The enhanced use of systems like Earth leakage detector and Data logger have been identified for condition based monitoring of signalling assets. An introduction to upcoming technology Remote Diagnostic & Predictive Maintenance (RDPM) using Machine learning and Artificial Intelligence has also been covered.

We are sincerely thankful to Signal Directorate, RDSO, Lucknow, M/s Efftronics System Pvt. Ltd., Vijayawada, M/S Anu Vidyut, Roorkee, M/s Energy7, New Delhi and S&T personnel of Indian Railways who helped us in preparing this handbook. Since technological upgradation and learning is a continuous process, you may feel the need for some addition/modification in this handbook. If so, please give your comments on email address dirsntcamtech@gmail.com or write to us at Indian Railways Centre for Advanced Maintenance Technology, In front of Adityaz Hotel, Airport Road, Near DD Nagar, Maharajpur, Gwalior (M.P.) 474005.

CAMTECH Gwalior

Dinesh Kumar Kalame
Joint Director (S&T)

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Issue of correction slips

The correction slips to be issued in future for this report will be numbered as follows:

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Where "XX" is the serial number of the concerned correction slip (starting from 01 onwards).

CORRECTION SLIPS ISSUED

Sr. No. of Correction Slip	Date of issue	Page no. and Item No. modified	Remarks

Disclaimer

It is clarified that the information given in this handbook does not supersede any existing provisions laid down in the Signal Engineering Manual, Railway Board and RDSO publications. This document is not statuary and instructions given are for the purpose of guidance only. If at any point contradiction is observed, then Signal Engineering Manual, Telecom Engineering Manual, Railway Board/RDSO guidelines may be referred or prevalent Zonal Railways instructions may be followed.

Our Objective

To upgrade Maintenance Technologies and Methodologies and achieve improvement in Productivity and Performance of all Railway assets and manpower which inter-alia would cover Reliability, Availability and Utilisation.

If you have any suggestion & any specific comments, please write to us:

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CAMTECH Publications

CAMTECH is continuing its efforts in the documentation and up-gradation of information on maintenance practices of Signalling & Telecom assets. Over the years a large number of publications on Signalling & Telecom subjects have been prepared in the form of handbooks, pocket books, pamphlets and video films. These publications have been uploaded on the internet as well as railnet.

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Abbreviations

Abbreviation	Description
AC	Alternating Current
AI	Artificial Intelligence
AFTC	Audio Frequency Track Circuit
ASM	Assistant Station Master
AT	Auxiliary Transformer
BHMU	Battery Health Monitoring Unit
BPAC	Block Proving by Axle Counter
CAMTECH	Centre for Advanced Maintenance Technology
CEL	Central Electronics Limited
CLS	Colour Light Signal
CMU	Central Monitoring Unit
COTS	Commercially Off The Shelf
CT	Cable Termination
DAC	Digital Axle Counter
dB	Decibel
DC	Direct Current
E1	European format for digital transmission
EI	Electronic Interlocking
ELD	Earth Leakage Detector
FEP	Front End Processor
FTU	Field Transmission Unit
GUI	Graphical User Interface
GSM	Global System for Mobile Communications
HASSDAC	High Availability Single Section Digital Axle Counter
HMU	Health Monitoring Unit
HQ	Headquarters
IoT	Internet of Things
IPS	Integrated Power Supply
IRS	Indian Railway Specification
LAN	Local Area Network
LED	Light Emitting Diode
LoRA	Long Range Communication (A wireless Technology)
ML	Machine Learning
MLB	Microcontroller Logic Block
MTBF	Mean Time Between Failures
MTTR	Mean Time to Repair
MS	Mild Steel
MSDAC	Multi Section Digital Axle Counter
NMDL	Network Management of Data Logger
NMS	Network Management System
OCC	Operation Control Centre
OEM	Original Equipment Manufacturer
OFC	Optical Fibre Communication
PC	Personal Computer
PF	Potential Free

PFC	Potential Free Contact
PHMU	Point Health Monitoring Unit
PI	Panel Interlocking
PR	Preparatory relay
RDPM	Remote Diagnostics & Predictive Maintenance
RDSO	Research Designs & Standards Organisation
RF	Radio Frequency
RRI	Route Relay Interlocking
RTMS	Real Time Monitoring System
RTU	Remote Terminal Unit
RUL	Remaining Useful Life
SCC	Signal Conditioning Card
SD	Secure Digital
SIM	Subscriber Identity Module
SM	Station Master
SMS	Short Message Service
SPD	Surge Protection Device
SSDAC	Single Section Digital Axle Counter
S&T	Signal & Telecommunications
STM	Synchronous Transport Module
TCP/IP	Transmission Control Protocol/Internet Protocol
TR	Track Relay
TPR	Track Proving Relay
UFSBI	Universal Fail Safe Block Interface
UPS	Uninterrupted Power Supply
USB	Universal Serial Bus
UTS	Universal Type Server
VR	Vital Relay
WLAN	Wireless Local Area Network

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Chapter I
Maintenance practices of Signalling Assets

1.1 Introduction

The Railway signalling system is supposed to provide safer, accident-free operation and at the same time ensuring punctual and reliable management of train movement.

The main objectives of S&T department are:

- To ensure **reliability** of assets.
- To ensure **availability** of Signalling system
- To ensure **safety.**
- To improve **efficiency** in train operations.

To achieve these objectives, following are the challenges faced by S&T department:

(i) Too many number and variety of assets to maintain

(ii) Distributed assets exposed to all types of weathers

(iii) Sensitive & sophisticated equipment affected by temperature, dust, voltage surges etc.

(iv) Assets affected by outside interference.

(v) Rapid introduction of new technologies

(vi) Insufficient skilled personnel for maintenance

(vii) Dependency on other departments

(viii) Containing the cost of maintenance

The types of maintenance practices which are normally adopted for maintenance of any asset are classified as:

I. Corrective &

II. Preventive

Preventive maintenance is further classified in three types namely:

- Periodical
- Condition based
- Predictive

For flawless performance of assets, the best practices among the above has to be adopted. The details of above maintenance practices along with comparison are given in the following sections.

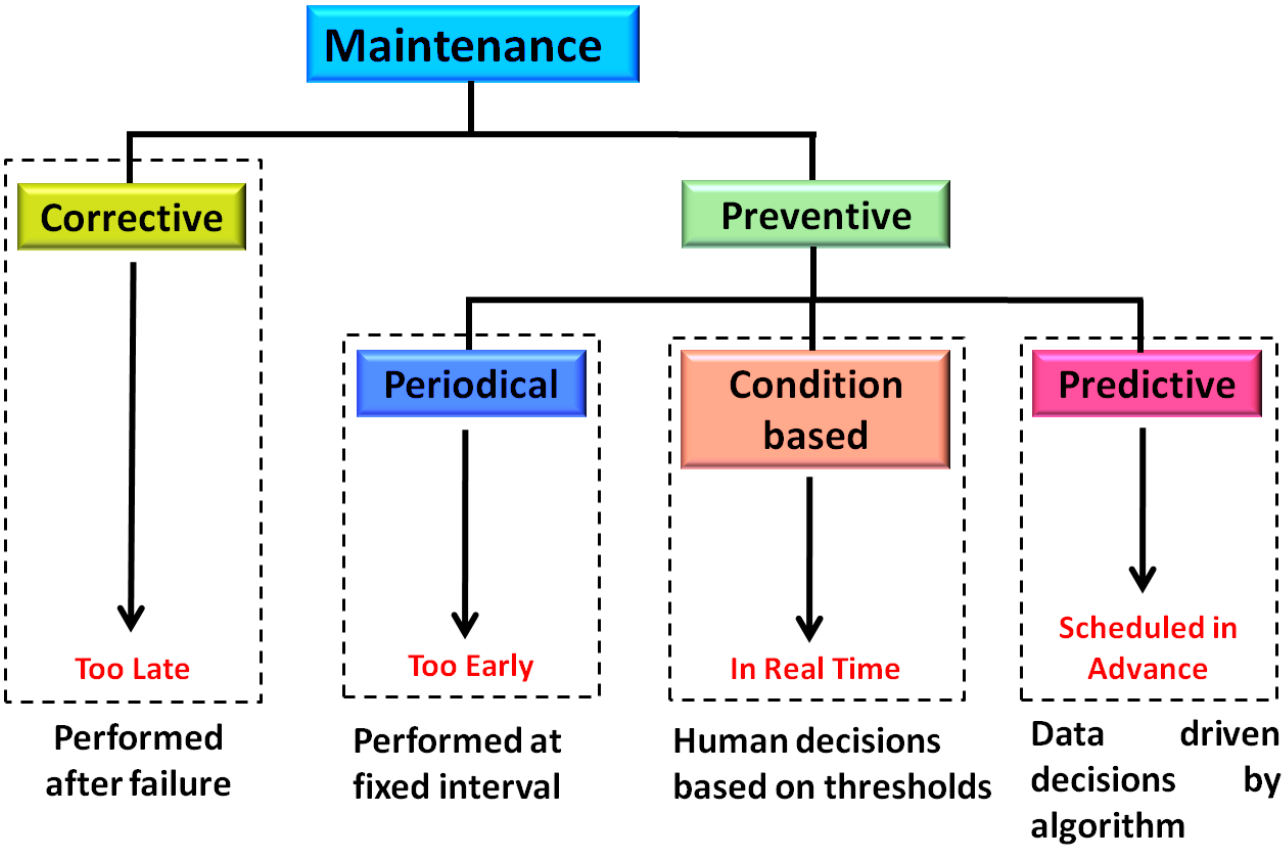


Figure 1: Classification of maintenance procedures

1.2 Corrective Maintenance



In corrective maintenance, the asset is attended only when it fails, and restored to normalcy. The repair work is conducted after a failure or breakdown. Time taken to restore the failure includes time to reach at site and actual time taken to rectify the fault. Otherwise known as the "fix it when it breaks" method of maintenance, it has a major drawback, the cost to repair or replace equipment that has been run to failure is usually significantly higher than if issues were detected and fixed earlier on. Skilled manpower is required depending upon type of asset. Generally spares have to be kept as standby.

1.3 Preventive maintenance

In preventive maintenance, certain periodical activities as recommended by OEM are carried out in advance to prevent failures. Sometimes railways, prepares these activities based on experience. Preventive maintenance can be done in three ways:

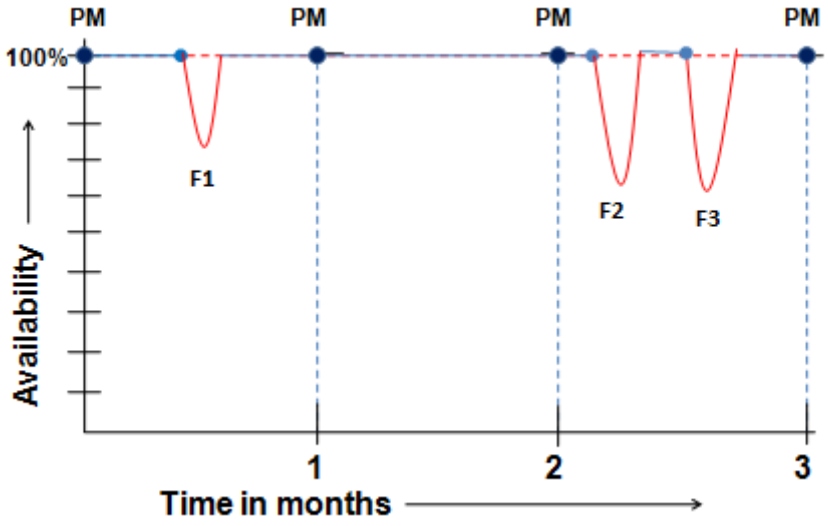
1.3.1 Periodical maintenance



In periodical maintenance, equipment is attended within a specified time interval irrespective of its state. The periodicity is either decided by railways based on the past experience or recommended by OEM. With regularly scheduled service, whether it is needed or not, equipment will remain relatively reliable until such time as it naturally begins to wear out. Knowing about the wearing out phase is relied up on general estimates and averages instead of actual statistics on the condition of specific equipment. This has two disadvantages:

a. Costly and completely unnecessary, maintenance taking place before there is any actual problem
b. Attending to maintenance leads to down time of equipment, reducing its availability.

Periodical maintenance consists of a specified list of inspections, cleaning, testing and part replacement during a pre-defined, time-based schedule. In *Figure 2* below, in the first month the asset has failed once, in the second month it is not failed and in the third month it failed twice even when periodical maintenance is done every month.



PM - Periodical Maintenance, F1, F2 & F3 - Failures

Figure 2: Graph depicting Periodical maintenance methodology

1.3.2 Condition based maintenance



In condition based maintenance, the health parameters of equipment are measured continuously with the help of sensors (for measurement of current, temperature, vibration etc.). Maintenance is done on the basis of parameters value. Human element is involved in deciding value for taking up maintenance. Condition-based maintenance (CBM) is a maintenance strategy that monitors the actual condition of an asset to decide what maintenance needs to be done. CBM dictates that maintenance should only be performed when certain indicators show signs of decreasing performance or upcoming failure. In fact condition-based maintenance relies only on real-time sensor measurements. Once a parameter reaches an unacceptable level, maintenance personnel are dispatched. This means that condition-based maintenance systems perform work only in the moment it is needed.

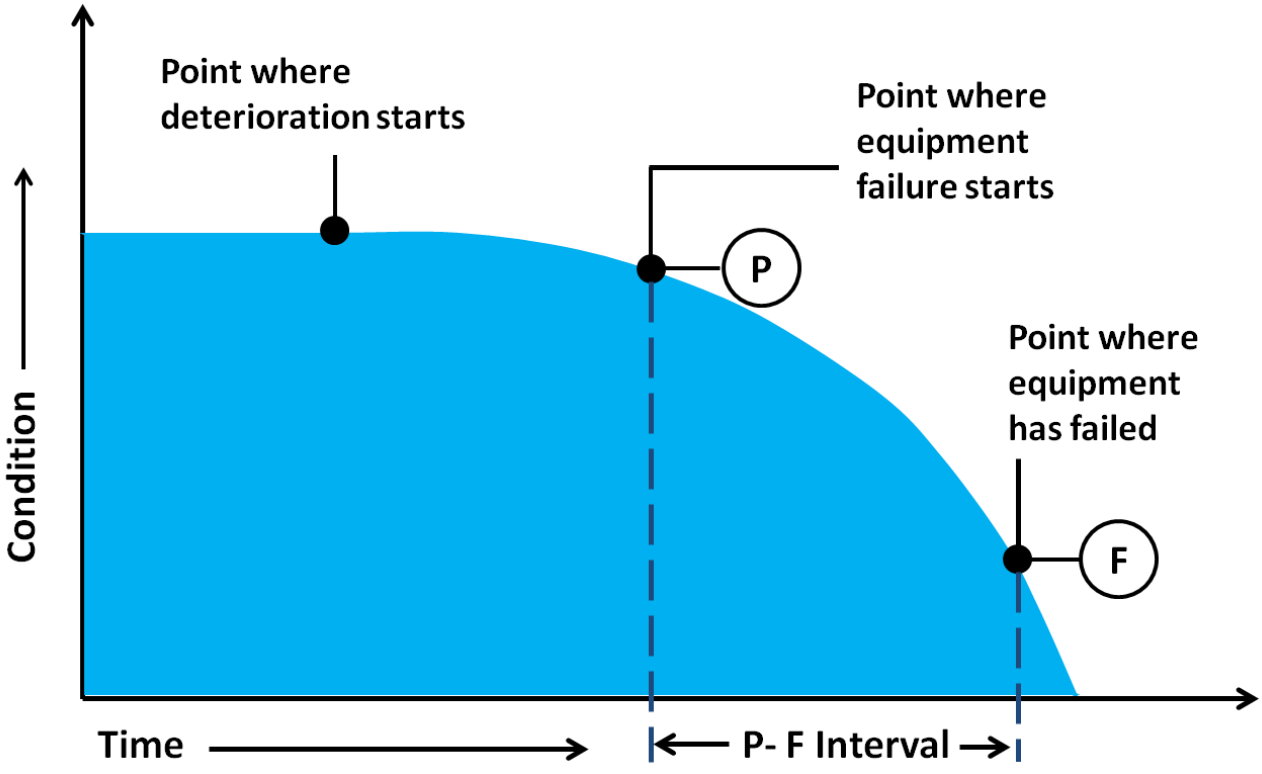


Figure 3 : Graph depicting the concept of Condition based maintenance

The "P" in the P-F curve of *Figure 3* refers to potential failure (when a piece of equipment *could* fail based on historical data, or the first point where we can detect that a

failure could be occurring). Conversely, the "F" refers to an asset's functional failure (when the asset *actually* fails).

1.3.3 Predictive maintenance



Predictive maintenance relies on precise formulas (algorithm) in addition to sensor measurements (temperature, vibration, noise), and maintenance work is performed based on the analysis of these parameters. Predictive maintenance integrates condition based diagnostics with predictive formulas. The data collected through sensors is analyzed using predictive algorithms that identify trends with the aim of detecting when an asset will require repair, servicing, or replacement. In this way, predictive maintenance is a very exact form of maintenance because it predicts future maintenance events. Before parameters reaching failure state, they are brought to normal value by attending equipment. This is more scientific; it requires fewer efforts and improves availability of equipment. Predictive maintenance schedules are based on diagnostic evaluations and other factors like uses of asset, site conditions, environmental stresses, criticality of equipment etc.

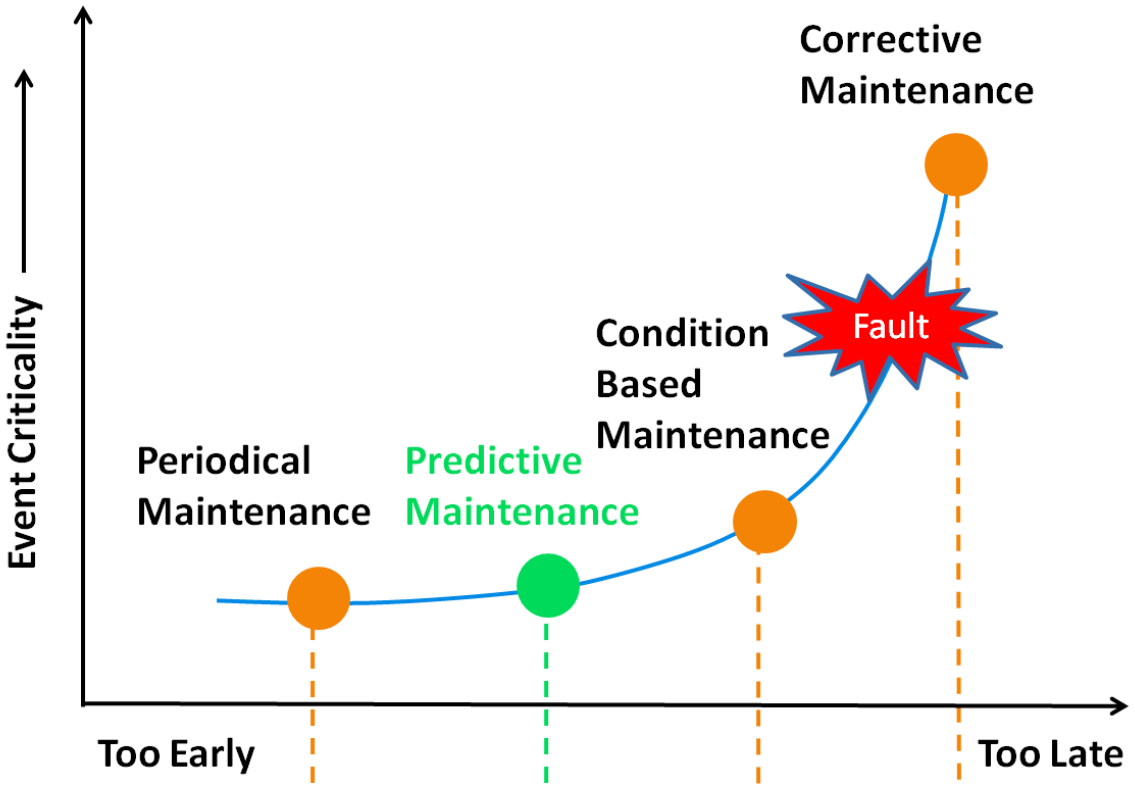


Figure 4: Concept of Predictive Maintenance

1.4 Need for Predictive Maintenance

In the preceding sections we have seen the limitations and drawbacks of corrective and periodical maintenance practices. To ensure availability of signalling system all the time and to meet the challenges faced by S&T department as given in Section 1.1, maintenance of signalling assets by condition monitoring combined with data analysis is the key. By condition monitoring of equipment, the deterioration can be tracked in real time and early action can be taken to restore its remaining useful life (RUL) with the help of predictive maintenance based on algorithm. This requires:

- Sensing health parameters of the equipment.
- Communicating the health data to a central location.
- Analysing health data to provide actionable decisions.
- Dissemination of actionable decisions to all concerned.

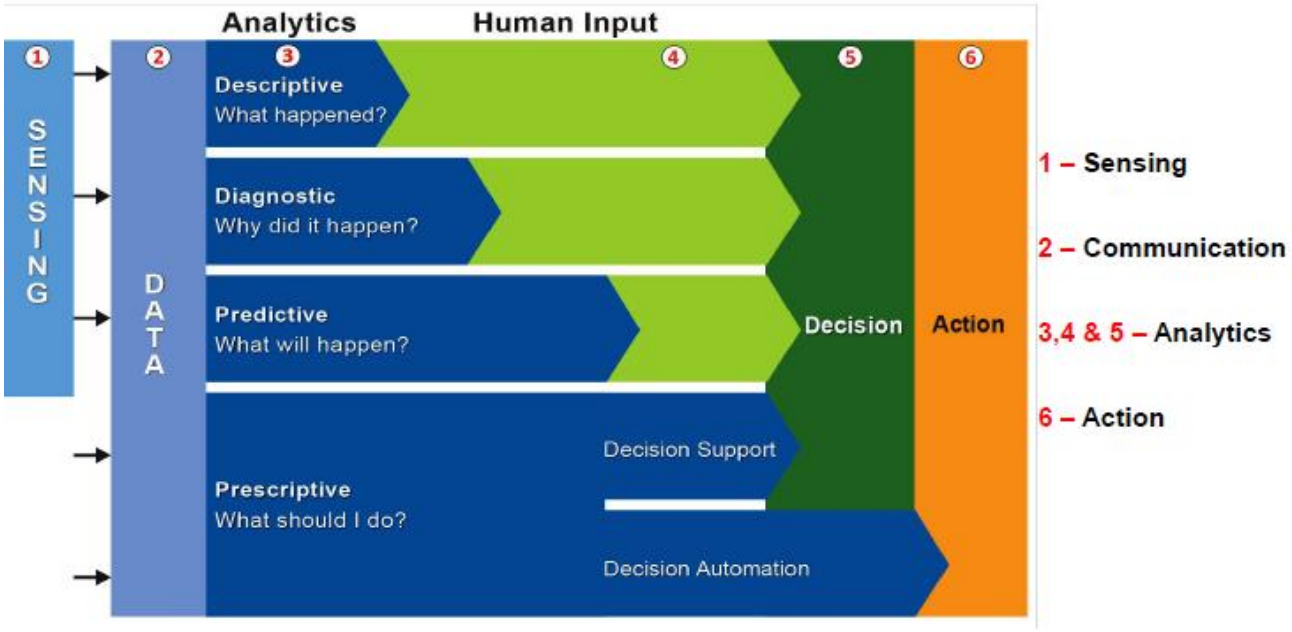


Figure 5: Data driven decisions by Data Analytics

Predictive maintenance of equipment can be done in following ways:

(i) With the help of internal diagnostic systems in equipment for example IPS, SSDAC, MSDAC, EI etc.

(ii) By providing external diagnostic systems for example ELD and Data Logger.

(iii) By using machine learning by skimming large amount of diagnostic data gathered over a period, covering different scenarios – and applying Artificial Intelligence [AI] – based on current data; it is possible to predict a failure.

1.5 Purpose of Predictive Maintenance

The main purpose of Predictive maintenance is:

1. Ensure availability of signalling system
    - Reduce MTTR - insights of incidences
    - Increase MTBF - insights into system
        - Predictive Alarms
        - Health Reports
2. Deskilling of Maintenance activities
3. Collaborative working with OEMs
4. Reduction of Maintenance efforts
5. Provide data driven decisions

1.6 Benefits of Predictive maintenance with Condition Monitoring

1. Mean time to repair (MTTR) is reduced as insight into the failure is provided by condition monitoring system.

   Mean Time To Repair (MTTR) refers to the amount of time required to repair a system and restore it to full functionality. Less MTTR is considered better.

   The MTTR clock starts ticking when the repairs start and it goes on until operations are restored. This includes:

    - Detection of failure.
    - Communication to Maintainer.
    - Reaching site by Maintainer.
    - Rectification of failure by Maintainer.
    - Return to normal operations after testing.

$$\text{MTTR} = \frac{\text{Total Repair Time}}{\text{Total number of Repairs}}$$

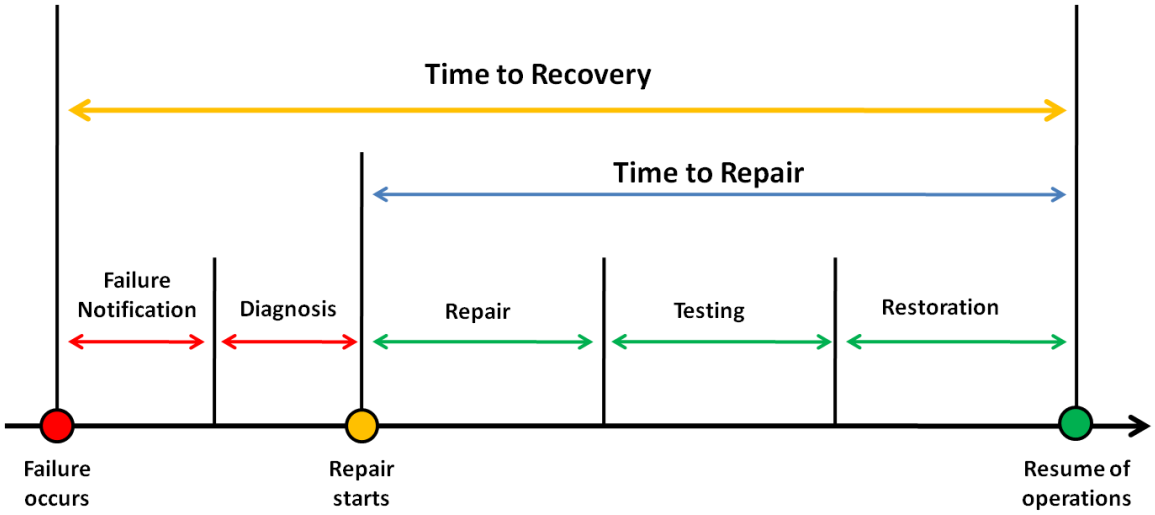


Figure 6: Graph depicting stages of recovery of an asset after failure

2. Mean time between failures (MTBF) is increased (Reduction of number of failures) as the equipment is attended before it fails based on Remote Condition Monitoring data.
   MTBF measures the predicted time that passes between one previous failure of a system to the next failure during normal operation. In simpler terms, MTBF helps to predict how long an asset can run before the next unplanned breakdown happens.
   More MTBF is always aimed at.

$$\text{MTTR} = \frac{\text{Total Operational Time}}{\text{Total number of Failures}}$$

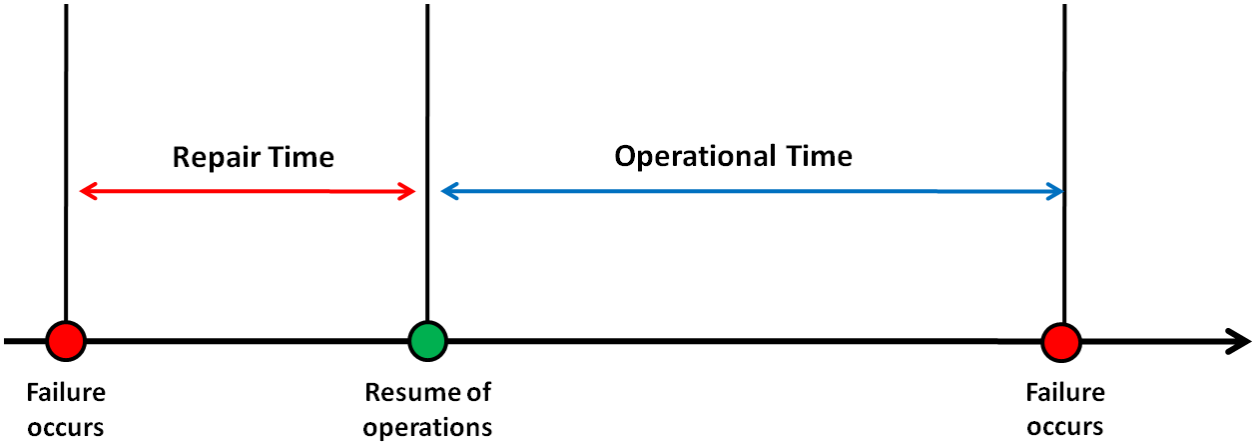


Figure 7: Graph depicting concept of MTBF

3. Maintenance cost is reduced as less skilled staff in the field can be guided easily by high skilled staff from central location and the maintenance time is reduced based on the state of equipment.

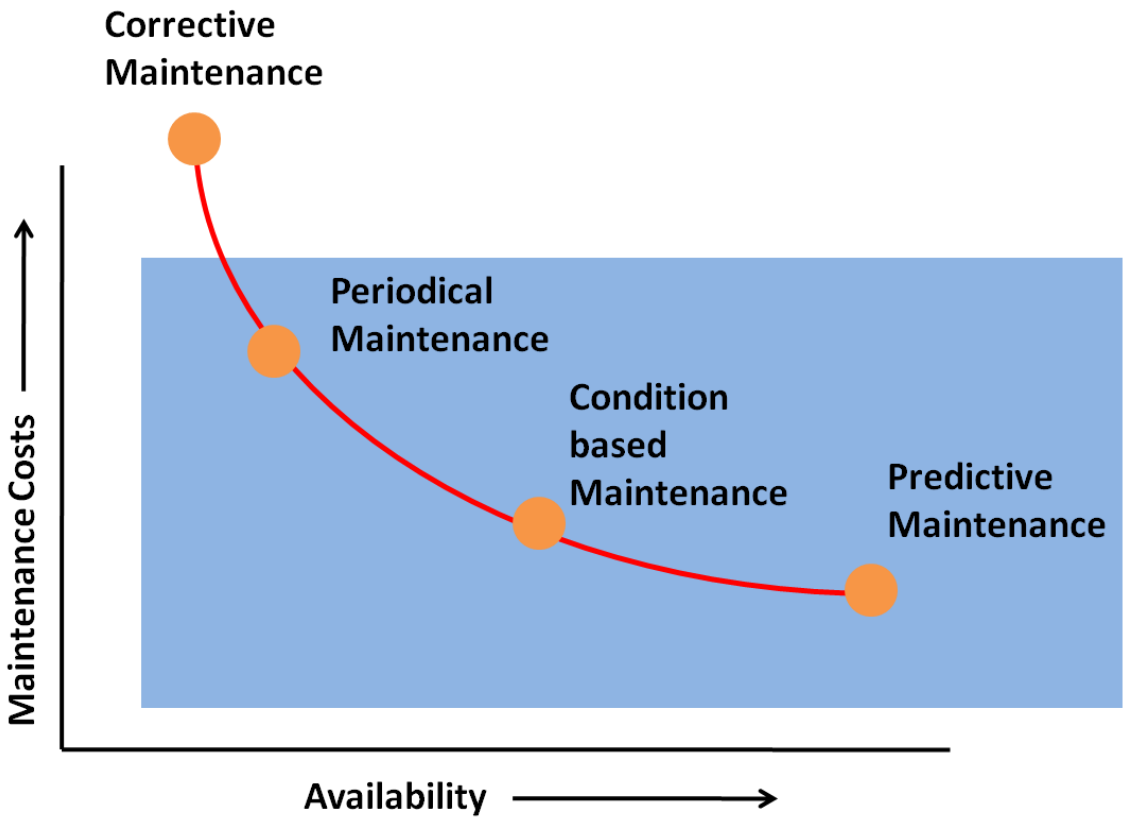


Figure 8: Graph showing Availability versus Cost of Maintenance

In the following sections, the external systems used for predictive maintenance are dealt.

Chapter II
Earth Leakage Detector

2.1 Introduction

The reliability of Signalling cables is important for working of the railway signalling system. Earth Leakage Detector (ELD) is a device which continuously monitors the earth leakage in signalling cables, loads (as point machine, signals etc.), circuits & power supply and gives alarm before earth fault, thereby increasing the efficiency and reliability of the Signalling system. The ELD conforms to RDSO specification no. RDSO/SPN/256 /2002. To understand the concept of ELD, one should have basic knowledge of Insulation resistance and Leakage resistance.

Insulation resistance

Insulation is the property of insulated material and can be measured in off line condition.

Leakage resistance

Leakage is also property of insulated material and can be measured on line condition.
A block diagram showing basic wiring connections of ELD is given below:

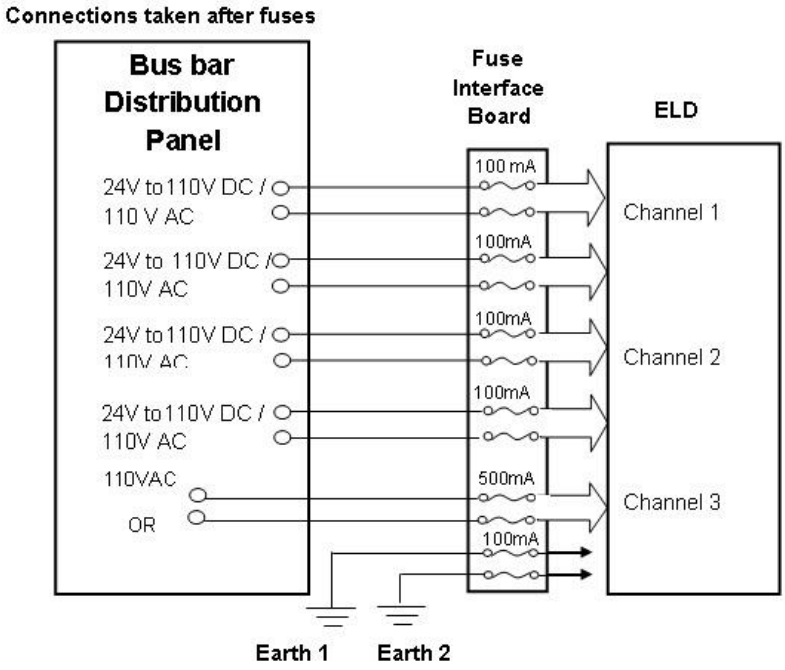


Figure 9: Block diagram of basic wiring connections for ELD

How an ELD indicates leakage?

ELD constantly monitors & measures Leakage Resistance of Bus Bar with respect to Earth in on-line condition.
Leakage Resistance can be read on meter.
When Leakage Resistance value drops below reference value, fault is detected; which is either announced as audio and/or visual alarm.
Fault can be recorded by counter / Data logger.
Reference value can be set anywhere between 1M to 2K (Factory setting on 2K).

We shall take the example of ELD of RDSO approved firm M/s Anu Vidyut, Roorkee.

2.2 Multi Channel Earth Leakage Detector type 905-B2 (M/s Anu Vidyut Roorkee)

Brief description

All the channels of the equipment continuously monitor the Leakage Resistance of the system w.r.t Earth and an alarm is actuated along with a visual Indication when the leakage resistance value drops to the pre-set value. The particular channel with Fault is automatically reset to Normal when the leakage resistance improves and reaches above the preset value.

Fault detection can be set in between 2K- 1M_ .The audio alarm is common for all Channels while the visual indication is separate for each channel. The basic unit comprises of 4 channels for use on signaling circuit of 110V AC or 110V/60/24V/12V DC. For more than 4 channels, say 8 or 12 channels, add on units are provided to be connected to the basic unit with suitable interconnecting cable/s and switches. The equipment also consists of an insulation resistance meter which can be connected to any individual circuit to indicate the actual value of the insulation resistance of the signaling circuit during un energized condition i.e. off-line condition.

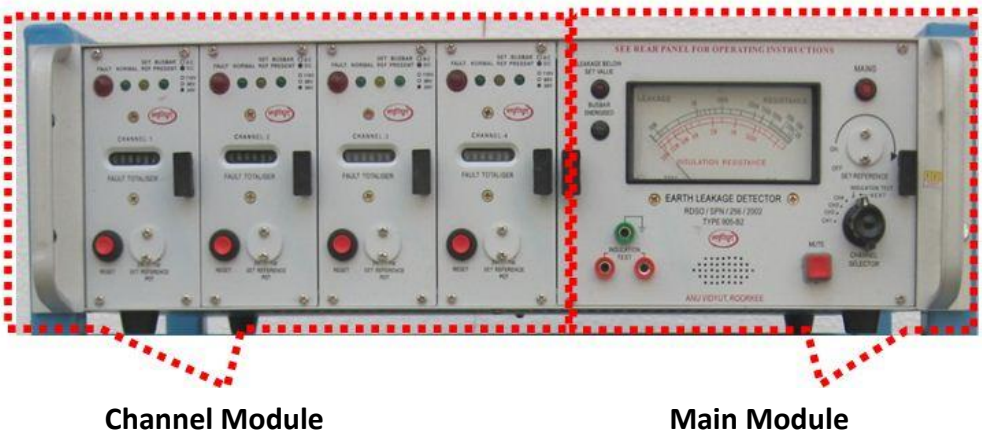


Figure 10: ELD equipment front view

Technical specifications

AC Mains	: 110V/230V AC, 50Hz.
Signaling Supply	: 110V AC or 110V/60/24V/12V DC - as required by the user.
Leakage Setting Range	: 2K -1M through a helical potentiometer.
Meter Range	: 2K -10M on an analog meter with wide scale.
Terminals provided for	: Remote indication, Remote Buzzer & Relay Contacts (1C/O)

Controls and Indications

Various controls and indications are provided on the front plates of the 'Channel module' and 'Main module' (Cable Insulation Tester), the details of which are under 'Controls and Indications'.

Main Panel

Mains : Red LED (A)
Set Reference : Potentiometer switch to select leakage Value to set reference (B)
Channel Selector : To select meter for particular channel/Insulation and Setting Reference. (C)
Mute : Push switch to mute the Alarm (D)
Test : To connect the cable pair under measurement (E)
Earth : To connect cable sheath (If earth) or earth (F)
Meter : Reads bus bar to earth leakage or insulation resistance as per the position of switch (G)
Pair Energized : Green LED (H), ON when cable pair connected to circuit (Measurement not possible**)**
Low Insulation : Red LED. ON when insulation resistance is lower than or equal to the set value, otherwise OFF.



Figure 11: Controls & Indications of Main Module

Insulation resistance meter

Reference Setting Range : Either of 500K, 1M, 1M5, 2M, 5M, 10M
Meter Range : 500K -50M

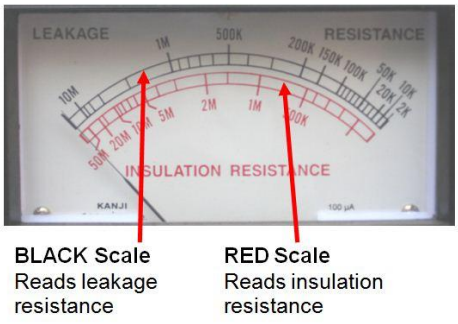


Figure 12: Meter for display of Leakage & Insulation Resistance

Channel Panel

Normal	: Green LED
Channel Set Ref	: Amber/Green LED
Fault	: Red LED
Bus- Bar voltage presence	: Green/White LED
SET REF POT	: Pot to set reference in conjunction with Potentiometer on Main Panel

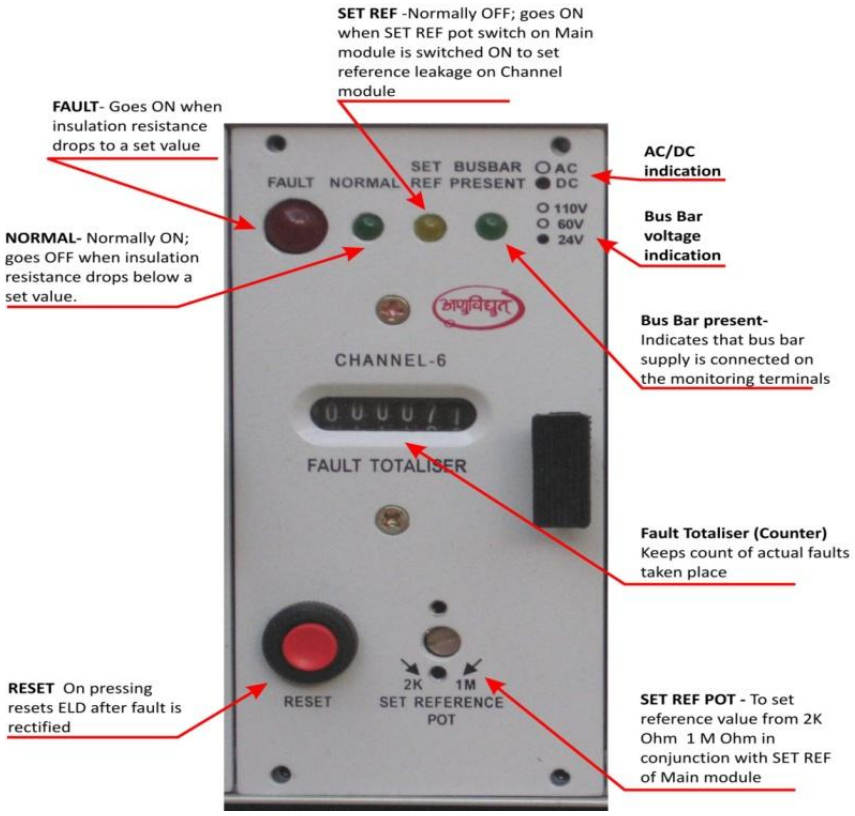


Figure 13: Controls & Indications of Channel Module

For detailed information on ELD, please refer Pocketbook on "Earth Leakage Detector" prepared by CAMTECH

Chapter III
Data Logger

3.1 Introduction

Data logger is a microprocessor based data acquisition system to log the changes in the status of Electrical Signalling System (relay contacts). Data can be accessed by a PC connected to data logger locally and generate simulation of train movements and alarms of signal failures, wrong operations and wrong movements. Data logger acts like a "Black box", which can scan, store and process the data for generating various user-friendly reports. When data logger is networked its data can be seen remotely at central location. Software provided in the PC at central location - provides real time and off line simulation and alarms which helps in analysing the signalling system. On Indian railways data logger conforms to specification No.IRS:S:99/2006.

3.2 Working principle

Data logger is a processor based embedded equipment.
It monitors –

i. Status of relays by monitoring one of the relays' contacts.
ii. Analogue voltages.
iii. Any potential free contact of signalling equipment like IPS health status contacts
iv. DC & AC currents [of point machines, DC track circuits, signal lamp currents etc.]

Digital Inputs

Relay inputs and AC/DC Voltages are required to be connected to the system for monitoring. Relay contacts are monitored as **digital inputs**. Maximum digital inputs of a data logger are limited to 4096. If the number is more two data loggers are provided.

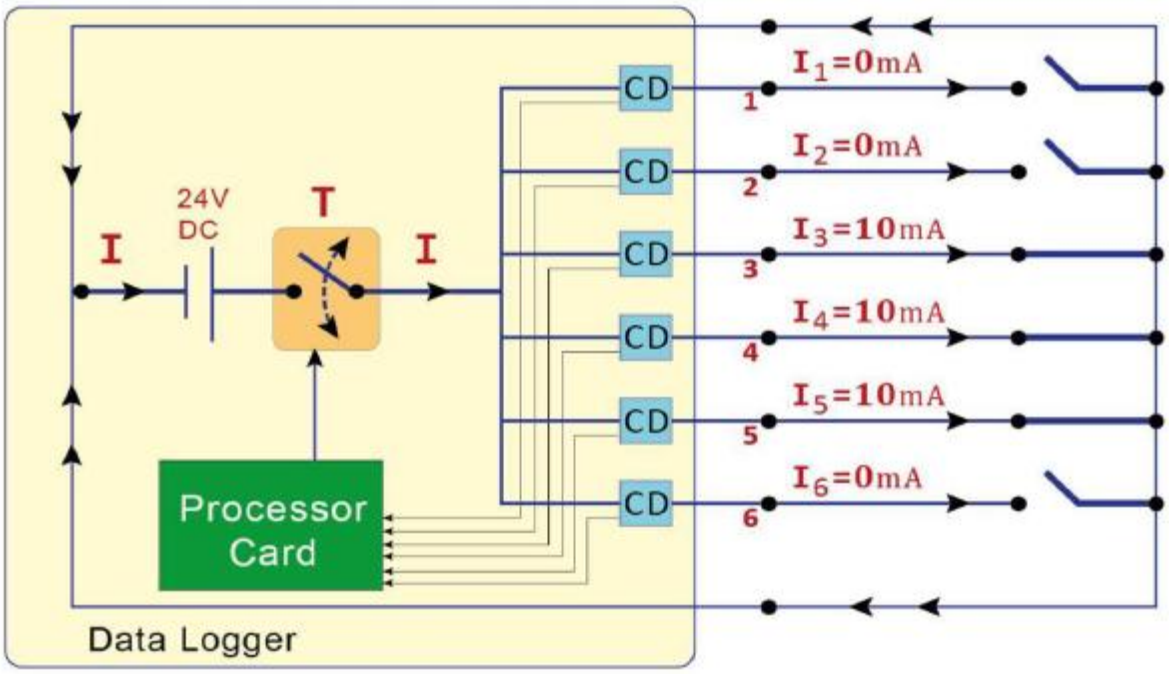


Figure 14: Electrical circuit of potential free contact monitoring by data logger
CD – Current detection, T – Switching Transistor (operates once in 8 milli seconds)

Processor card controls the switching transistor T by switching it on for every 8 milli seconds. When transistor closes, 24 V DC is applied to each input of data logger. If the contact wired to the input is in closed condition, current flows in the input. If contact is open, no current flows. Presence or absence of current is detected every 8 milli second i.e. when transistor applies voltage to input port. When there is change in status of contact, the current in the input also change. This information is sent to processor card for storing in the memory.

Analogue Inputs

Voltages are monitored as **analogue inputs.**
AC voltages are converted to DC while DC voltages are taken same as they are.

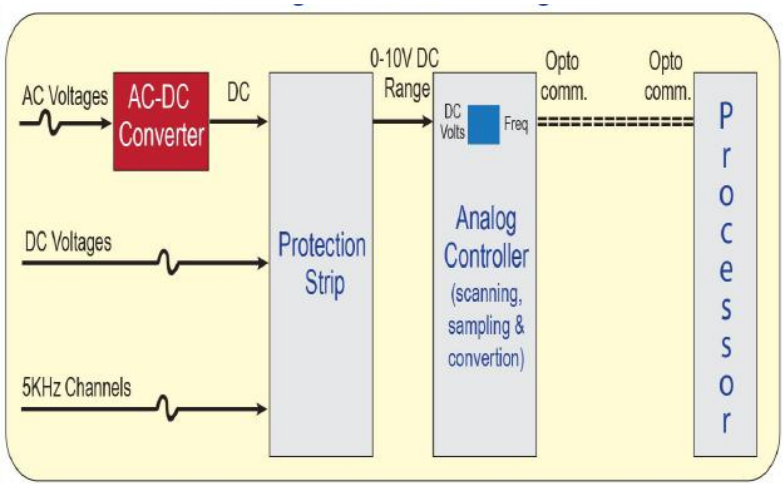


Figure 15: Analog Module Block diagram

Protection strip – provides isolation between the voltages being monitored and the data logger supply - converts the monitoring voltage into the scale of 0 to 10 Volts

Controller - samples once in 1 Sec – converts voltage to frequency and further into digital form and sends to data logger through OPTO communication

Processor in data logger – if the value is more than 5% of the nominal value – a packet is generated with time stamp and sequence number – another packet called analogue fault packet is generated if the value is beyond the user set limits entered in the data logger – this fault packet is meant for viewing at data logger.

At CMU – analogue value can be seen from the packets generated at **5% tolerance** – **analogue alarm** can be generated by setting the limits [these limits can be different from the limits set at data logger]

Based on the monitored parameters, alarms are generated for taking corrective action by maintenance staff.

3.3 Network of Data loggers

Data logger in various stations can be interconnected in a network with the use of Main Telecom cable or Quad cable or Microwave or OFC (Optical Fiber Cable). Data is brought to the centralized system called Front End Processor (FEP) which is connected to the station data loggers through the modems. FEP in turn is connected to a PC placed in Control room/HQ office called Central Monitoring Unit (CMU). The CMU is having the Graphical

User Interface (GUI) software to retrieve data from all networked data loggers. CMU collects the data from the FEP, stores it and processes for report generation and analysis.

Modules of data logger network system

The network of data logger system consists of the following modules:

- Data logger
- Remote Terminal Unit (RTU)
- Front End Processor (FEP)
- Central Monitoring Unit (CMU)

RDSO recommended data logger network

(Ref.: RDSO Letter no. STS/E/Data logger/Vol. XX dated 12.09.2011)

All Data logger networks shall be provided with Path, FEP, and Server and CMU redundancies. Typical network arrangement is given in *Figure 16*. .

The following are the features of the network:

- Number of data loggers connected to one FEP is limited to 32 numbers to meet the requirement of RDSO specification clause 4.3.2.
- Maximum number of data loggers in each string is limited to about 10
- Data is collected by two FEPs in the test room for redundancy.
- A standby PC is provided as CMU for redundancy.
- It is recommended to connect the data loggers with one another and to the central place by E1 Channels which are more stable and easily available compared to voice channels.
- A standby server is to be provided to ensure availability of data in case of failure of hardware or software.
- Data logger data has to be made available to all the concerned officials like zonal office and field supervisors on real time basis to enable them to take actions in case of accidents or incidences.
- To avoid viruses in the system the same it is recommended to provide fire wall.
- Data can be extended to **i**ntranets like RAILNET from the LAN Switch after the Firewall.

Data to Zonal HQ

Data shall be made available as given in the network diagram below to zonal HQ by extending the network of data loggers.

Data to railway board in case of accidents/ accidents/ disruption to train services

By becoming client to the divisional data base any user in railway board can access the data of the data logger. Connectivity at zonal level is also provided for redundancy.

Data to field officials.

Data shall be made available to **field officials** by extending the server data from test room.

Monitoring of data at EI stations

(i) A separate PC for monitoring the data of EI through data logger. Diagnostics monitoring PC of EI shall be separate.

(ii) Data monitoring through serial port and the input and output relays monitoring through conventional digital stack cards by wiring the potential free contacts.

In the Test Room, one screen shall be provided to CMU PC for monitoring Data Logger network and another bigger screen shall be provided for reports of station and failure display.

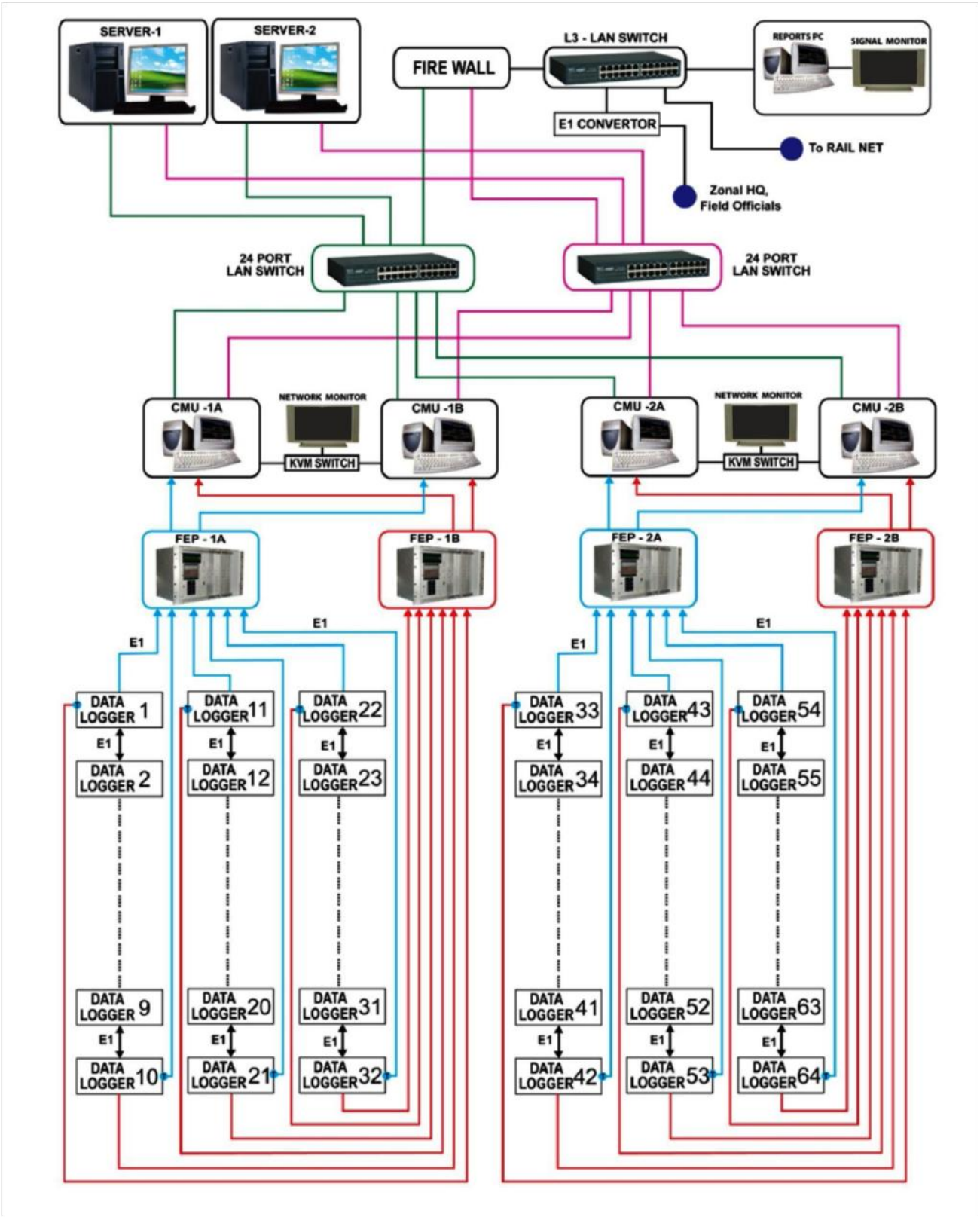


Figure 16: RDSO recommended Network of Data Loggers

3.4 Advantages of Data Logger

(i) Reduction of failure duration [MTTR]

Data logger detects the events [change of relay status or voltage] generated by signalling system - PC in test room generates alarms based on events and their sequence – alarms are sent as SMS to maintenance staff with a PC connected to mobile network with GSM modem with SIM card.

Mean Time to Repair (MTTR) is reduced because of intimation of failure to multiple staff without delay – and additional information of events.

(ii) Better analysis leading to root cause identification

Data logger system helps in better analysis as the status of power supply, other signalling elements, operations and train movements are made available.

(iii) Reduction of number of failures [MTBF]

Periodical data logger reports, helps in tracking the behavior of the equipment. Normally recorded failures only are taken into consideration while analyzing the equipment failures. Data logger system records every single event irrespective of its duration and its effect on train running. It gives complete picture of the equipment – thus leading to better analysis.

(iv) Monitoring signalling system performance and usage remotely by higher level supervisor

Three levels of usages:

(a) Low level: Front end maintenance staff – failure is to be conveyed fast with minimum technical details.

(b) Medium level: Supervisory level – to guide front end maintenance staff with more technical details – usage of statistical data for taking decisions to improve the system.

(c) High level: by managerial use at division level and HQ level - usage of statistical data for taking decisions to improve the system – occasionally, monitoring on real time basis.

3.5 How a Data logger system helps in corrective and preventive maintenance?

- Data loggers help in analyzing the failures such as intermittent, auto right in nature.
- Help in detecting the human failure/errors such as
  - Driver passing signal at danger.
  - Operational mistakes done by panel operators/ASMs of operating department.
- Real Time Alarms – enables prompt action by maintainer.
- Help in preventive maintenance of signalling gears.
- Real Time Status of Relays & Analog Voltages – Helps Remote analysis & Guidance for Failure Attendance
- Data loggers can be connected in the network which helps in monitoring PI/RRI/EI remotely.
- Failure reports can be generated remotely with the help of data logger network.
- Real Time (on-line) station Simulation.
- Offline Simulation & Status of Relays & Analog Voltages – for Failure Analysis & Accident Analysis.

- Age of the equipment in terms of number of operation/operating time can be calculated.
- Fault alarms generated by data logger system can be intimated to concerned staff, through SMS even though they are at remote place. This reduces Mean Time to Repair (MTTR).

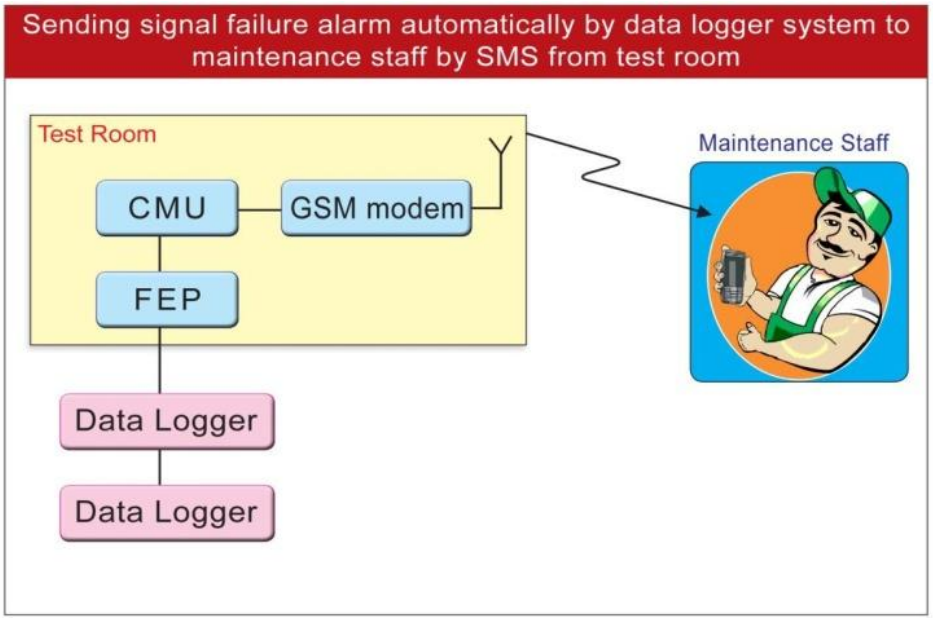


Figure 17: Block diagram for online SMS feature

Chapter IV
Predictive maintenance through Data logger

4.1 Introduction

Additional monitoring equipments have been developed by RDSO approved firm M/s Efftronics Systems Pvt. Ltd., Vijayawada enhancing the usage of Data Logger. Health Monitoring Units (HMUs) for various equipments listed below can help in predictive maintenance of signalling assets.:

(1). Underground Copper cable
(2). Electric Point Machine
(3). DC Track Circuit
(4). Secondary Battery
(5). Digital Axle Counter
(6). Electronic Interlocking
(7). LED Signal lamp
(8). Integrated Power Supply
(9). Air Conditioner
(10). Point operation against occupied line after arrival of train

The details are given in the following sections.

4.2 Earth Leakage Detection in copper cable

As explained in chapter III, the Leakage Resistance of Bus Bar with respect to Earth in on-line condition is important for a signalling system. Supply Leakage is a property of insulated material and can be measured in on line condition. The Leakage Resistance (or online system insulation) of a system is the combined Insulation of Power Supply, Insulation of Control circuits, Insulation of Cables and Insulation of loads all in parallel.

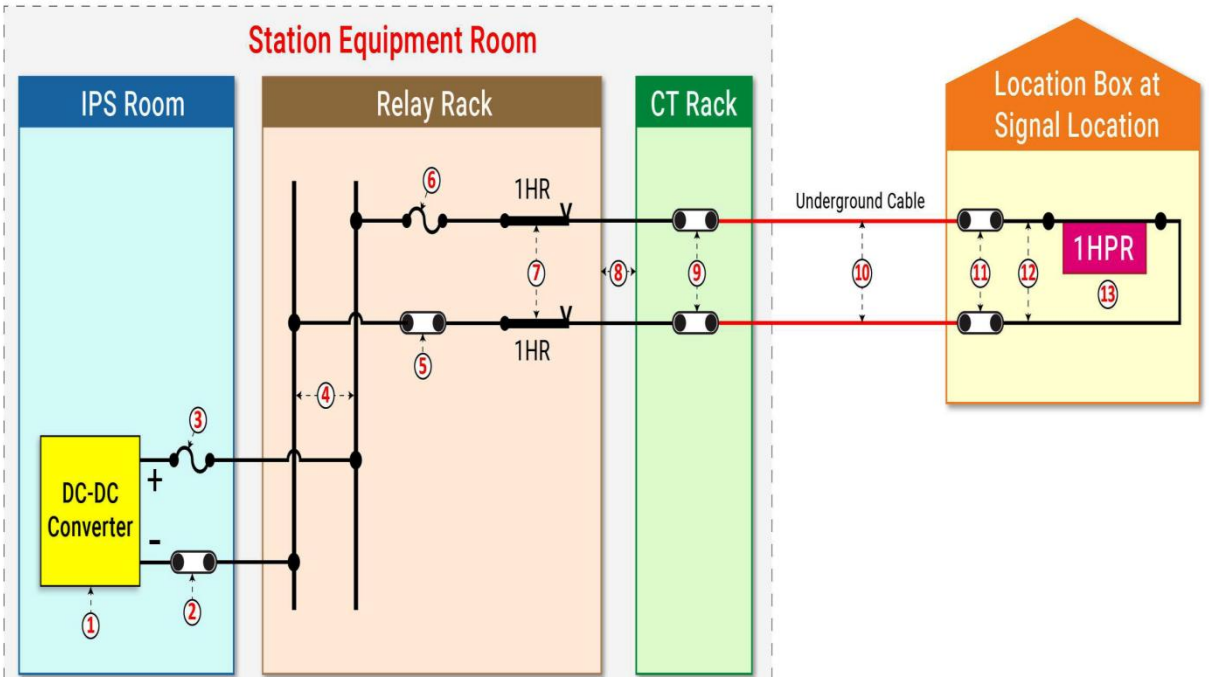


Figure 18: Various points of Earth Leakage in a circuit

In the *Figure 18* given above, a simple circuit for OFF aspect control repeater relay picking up in location box through the front contacts of HR in relay room is shown. On observing the circuit, there can be about 13 elements which can be the cause of earth leakage, namely:
(1) DC-DC Convertor (2) Terminal in output of negative supply (3) Fuse in output of positive supply (4) Bus bar in Relay room (5) Terminal in negative bus bar (6) Fuse in positive bus bar (7) Wiring on relay base plate (8) Internal wiring from contact to CT rack (9) CT rack terminals (10) CT rack to location box - Underground cable (11) Terminals in location box (12) Internal wiring in location box (13) Relay HPR
For example, if the base plate of a relay is cracked and go unnoticed, it may accumulate muck over a period of time which in turn attracts humidity. This may result in supply leakage.
Underground cable insulation loss is also one of the reasons of earth leakage.

Earth Leakage Detector Type 905-B2

ELD detects earth leakage and operates a potential free contact [PFC]. PFC is wired to a data logger. PFC remains in the same state until acknowledged by the maintainer. i.e. if earth leakage disappears in the present faulty circuit and reappears in some other circuit – ELD fails to detect. Because of this behavior of ELD; state of earth leakage does not correspond to

the position of PFC. Hence, data logger cannot identify the faulty conductor. This is the case if Anu Vidyut make Type 905-B2 ELD is used.

Need for improvements

Initially ELDs were developed for big installations like RRI where maintenance staff is available round the clock and they can keep them under observation and take action as and when required. These are now provided at small stations and unmanned installations like Auto location huts.

There is a need to revise the specification which requires that PFC operates on real time basis. It means that whenever there is a leakage, the PFC closes and as soon as the leakage disappears, it opens.

There is another drawback with present ELDs that they work on 230 V AC commercial supply instead of inverter supply. Whenever there is a power supply failure, ELD gives false alarms as PFC closes. It is recommended that ELDs should be made to work on 24 V DC.

Earth Leakage Detector Type 905-B4

A modified ELD Type 905-B4 has been developed in which PFC always corresponds to the state of the health of the cables. This ELD is same as the RDSO approved ELD except following three clauses from RDSO SPN-256/2000:

Clause 2.2.3 - A reset button shall be provided to re-energise the detecting relay after an earth fault has been indicated.

Clause 2.4.4 - The relay, once de-energised shall remain in that conditions until it is reset.

Clause 2.4.4.1 -The equipment shall be RESET by pressing push button switch, only after the fault has been rectified. Each RESET operation shall be recorded by a counter.

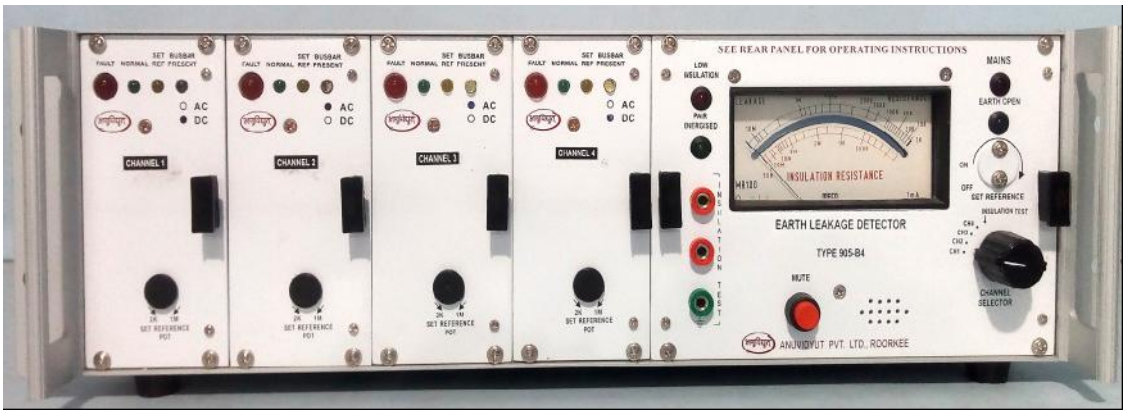


Figure 19: Earth Leakage Detector type 905-B4

Advantages of ELD Type 905-B4 over ELD Type 905-B2

(i) ELD Type 905-B4 supports complete automation as it is compatibly connected to Data logger and continuous output is provided to various levels of users through mobile interface;

(ii) Redundant parts like manual RESET switch and Counters are omitted from the equipment design.

(iii) Operationally, ELD Type 905-B4 helps in continuous monitoring of earth leakages/faults in comparison to ELD Type 905-B2 wherein the monitoring stops at first fault. Unless fault is removed or RESET button is operated the latter can't identify subsequent faults, which may be alarming and needs attention.

(iv) It clearly establishes that ELD Type 905-B2 works more or less in manual mode which demands physical presence of the user to operate RESET button and/or remove the fault.

ELD - Data logger Interface to detect cable pair with earth fault

The following alarm features of ELD and Data logger has been made use of in ELD - Data logger interface :

ELD Alarm1 - Supply Leakage occurred time.

ELD Alarm2 - Supply Leakage disappeared time

Data logger Alarm -Linking events of supply application and withdrawal to the function which uses this supply just before ELD Alarm.

(i) External defective cable pair responsible for earth fault can be identified by wiring diagnostic potential free contacts of ELD to data logger and identifying from data logger

a. Relays which power the conductors

b. Relays which are powered by the conductors

For this the arrangement for ELD - Data logger interface is as given in *Figure 20*.

- 24 V DC bus bar is extended to field locations.
- TPR , NWKPR & LXCR are operated from field to relay room.
- NWPR, HPR & CHYPR are operated from relay room to field.
- This is only for example, there can be more inputs in a big station
- All the six inputs can be monitored by data logger.
- ELD PFC can also be monitored by data logger.
- The input (relay) which closes before the ELD PFC is closed, indicates the pair with leakage which power the relay.

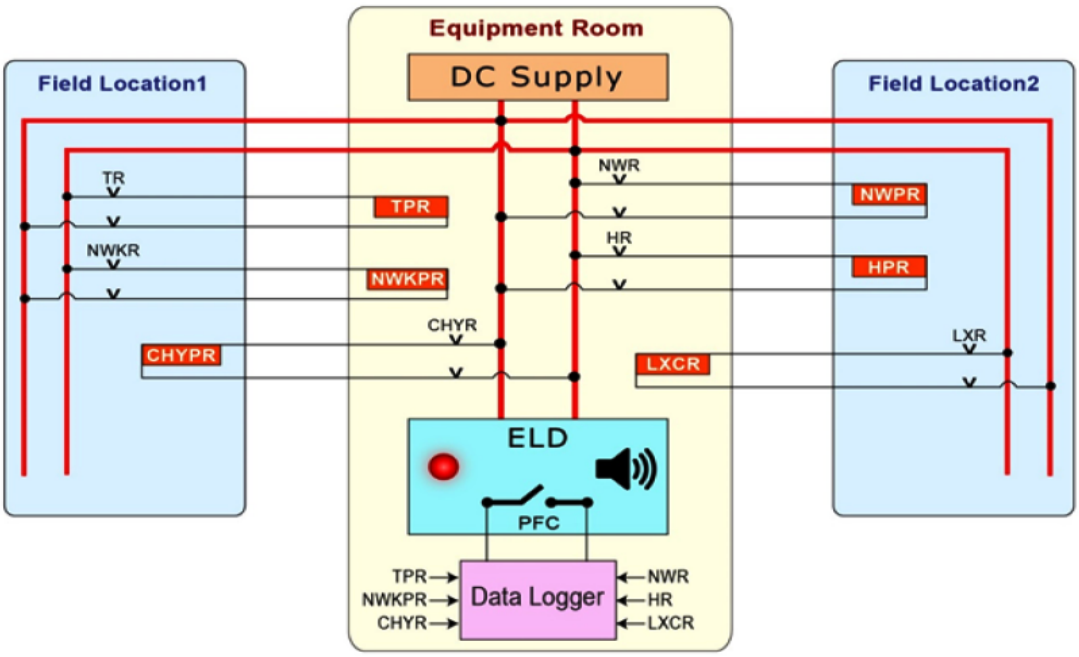


Figure 20: Application of Data Logger in Earth Leakage detection

(ii) Alarms are generated by a software provided in CMU [Central Monitoring Unit – a PC provided in the Control room/HQ office] which identifies the pair of cable conductors which are powered immediately before the alarm is generated by ELD.

Defective conductor identified twice –when both leakage appeared & disappeared.(if Specification is changed).

A snapshot of powered and non-powered pair of cable conductors can be provided for further analysis by the user.

The following type of message is given

Sr. No.	Station	Fault message
1	New Tundla	Earth leakage occurred on 110 V DC Point supply (ELD) at 13:49:16 Check for fault in the conductor of 231 NWR UP at 13:49:15
2	New Tundla	Earth leakage disappeared on 110 V DC Point supply (ELD) at 13:49:22 Check for fault in the conductor of 231 NWR DN at 13:49:21

(iii) The earth fault might be caused by the underground cable pair, terminals used to terminate the cable or the relay wiring or the signaling element powered by the pair [Ex: earthing of current regulator of CLS lamp, earthing of field coil of point machine, earthing of detection contacts of point machine etc.] Source: M/s Efftronics.

4.3 Point Health Monitoring Unit (PHMU)

Point is one of the most important elements in signalling. It has moving parts and prone to outside interference as it is distributed on the layout of tracks which comes under Civil Engineering department. Apart from this there are many more issues like, obstruction in point, wrong adjustment, ground connections rubbing against stock rails, sluggish operation etc. The root cause of all these type of problems can be detected early with the help of Point Health Monitoring Unit (PHMU) which can help in reducing the MTTR. This is explained in the following examples:

- If a point machine is failed to operate, it can be detected by PHMU. In this case its current is shown zero in the point Time-Current graph (Current signature).
- If a point operates sluggishly, the operation is successful but it takes more time as compared to normal time. The same is reflected in the current signature of point under consideration.
- If there is an obstruction in point, the maintainer gets correct information through PHMU, and he can straightaway go to the point and remove the obstruction instead of checking in relay room.
- If point machine ground connections are rubbing with the rails, the current signatures are altered. This type of abnormalities can be detected by seeing at the current signature graph.

These type of insights are given by PHMU hence the failures can be rectified in minimum time.

The following parameters are already monitored by data logger :

- Point Operation & Detection Relays.
- Point Operation & Detection Voltages. (110 V & 24/60 V DC)
- ELD contacts of Operation & Detection supplies. (110 V & 24/60 V DC)

Additionally, Point Health Monitoring unit monitors the following parameters:

- Point Machine Current.
- Point Voltage at point location.

Point health monitoring Unit for sequentially operated point machines with feed controlled from relay room

The working of this system is given in *Figure 21* below:

- Points 100 A & 100 B are operated sequentially from central place.
- One sensor of mini logger at CT rack detects current signatures of both point machines.
- Through event logger, data is provided to data logger.
- Data can be seen in the local PC or at central location.

The data logger gets six types of inputs as shown in the figure. (There can be more number of inputs depending upon the installation)

1 & 6 - Point operation relays NWR & RWR - Digital
2 & 5 - 110 V DC & 24 V DC - Analog
3 & 4 - ELD Potential Free contacts - Digital

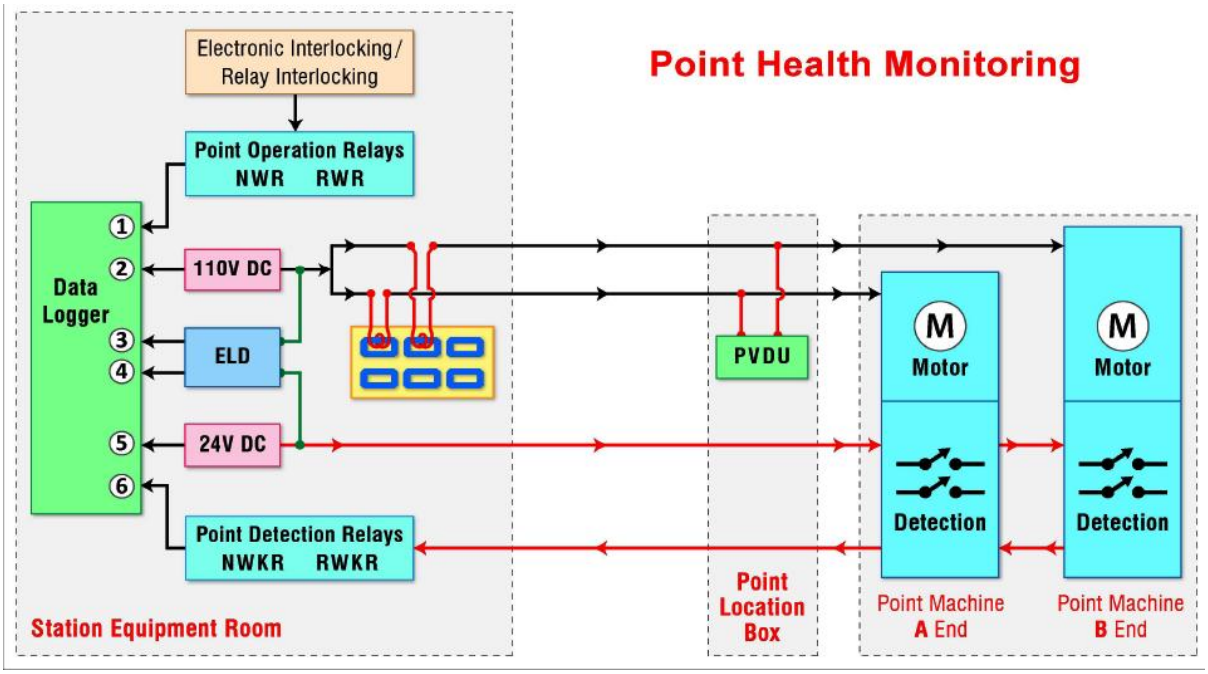


Figure 21: PHMU for sequentially operated point machines

The current sensor in PHMU detects current. It is installed on CT rack.

The Point Voltage Detection Unit (PVDU) detects voltage. It is installed in location box near point machine.

If the points are to be operated sequentially (in series), then one sensor itself will detect current of both the points.

If the point machines are wired to operate in parallel then two sensors are required to detect the current independently for each point.

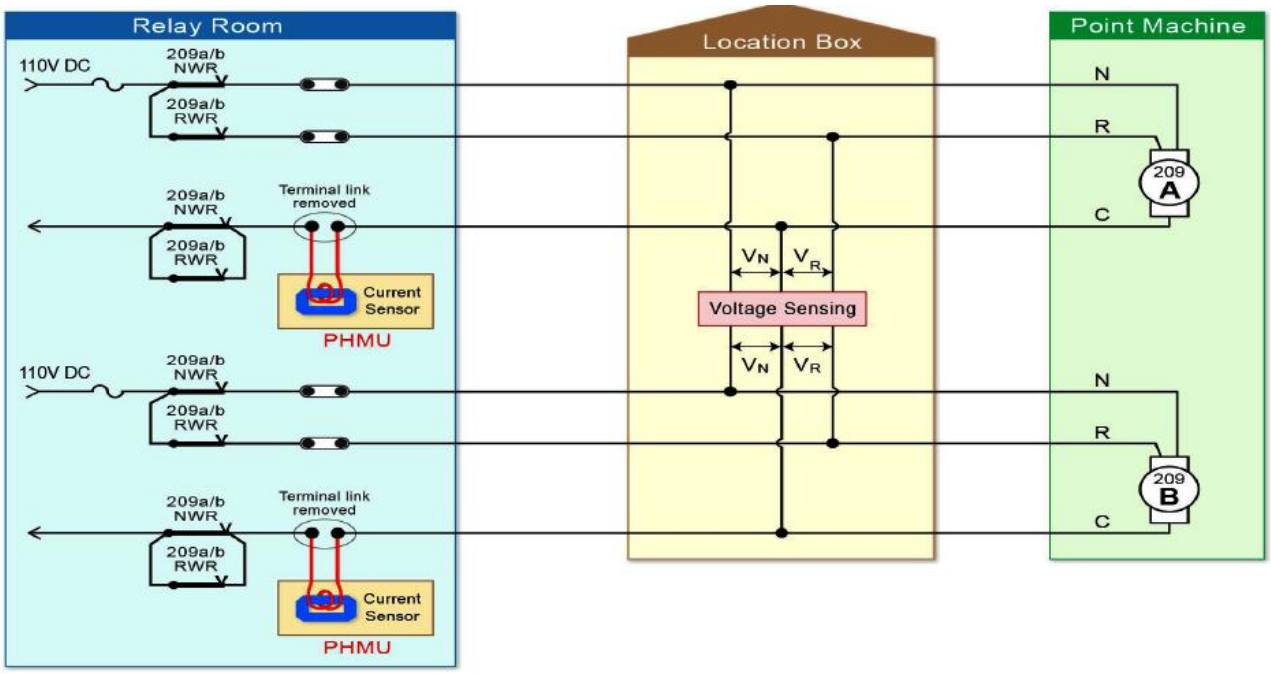


Figure 22: PHMU Connection diagram



Figure 23: Point Health Monitoring Unit actual view



Figure 24 : Point Voltage Detection Unit actual view

Current signature analysis

Current signature analysis in the form of Current-Time graph can be done with the help of Point HMU to detect the cause of failure such as:

- Carbon brush worn out.
- More current at locking time due to spring.
- Obstruction in point motor
- More friction due to lubrication problem
- Problem in unlocking
- Problem in locking position.

Some examples of current signature are given in the following pages:

In *Figure 25* , or a successful operation, a peak current and then a current of 2 to 2.5 Amps. is remains for about 3 seconds.

In *Figure 26*, for an unsuccessful operation, a peak current and then the low current of 2 to 2.5 Amps. remains for a very short duration and it rises to a higher value almost double the value of low current because of friction clutch. It remains for about 10 seconds.

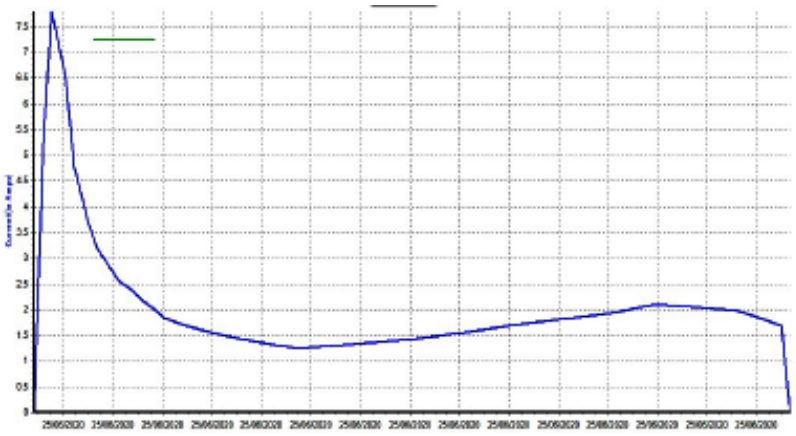


Figure 25: Current Signature of Point operation successful

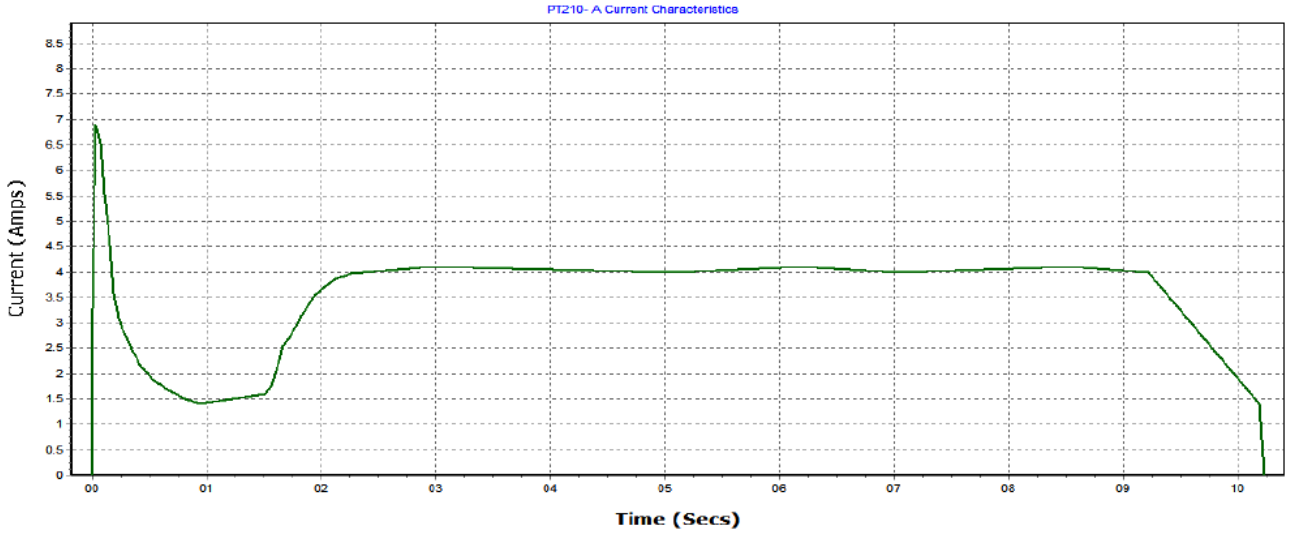


Figure 26: Current Signature of Point operation unsuccessful

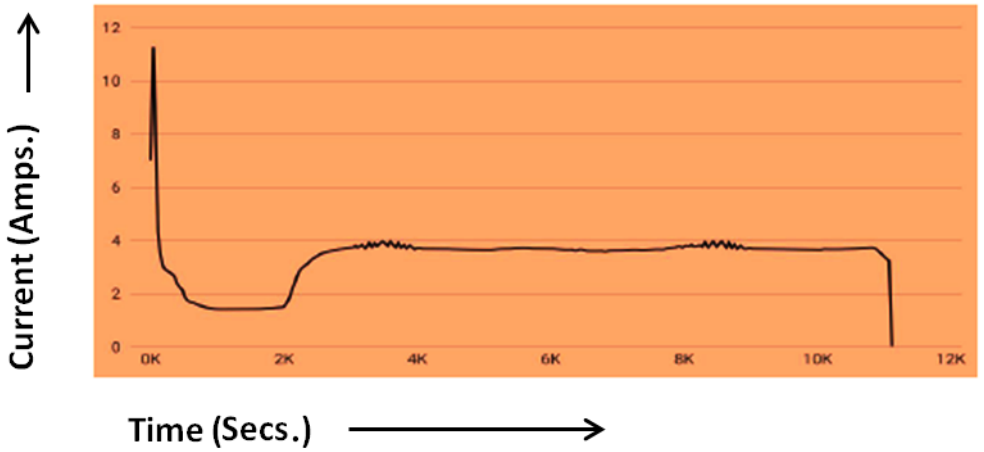


Figure 27: Current Signature of point lock fouling

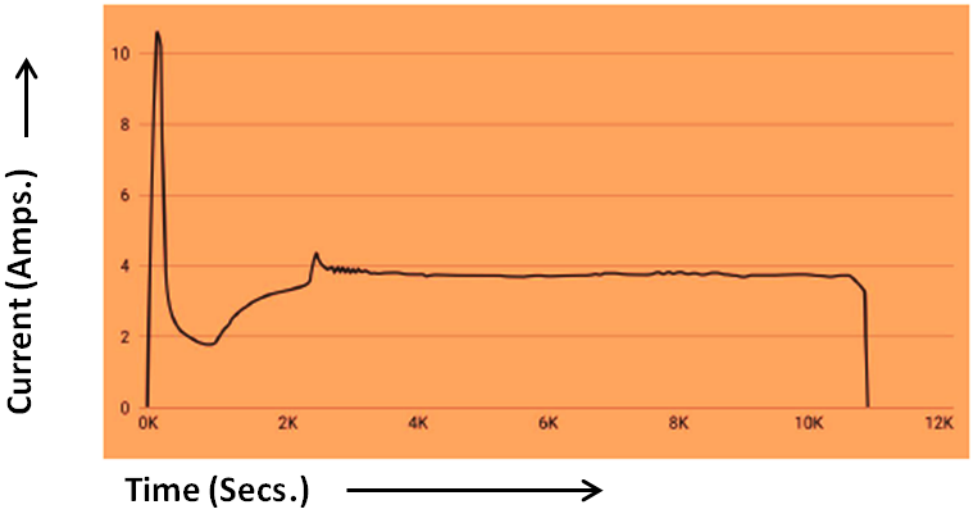


Figure 28: Current Signature of obstruction in point

Figure 27 above shows current signature of point machine with locking failure**.** Figure 28 shows current signature of point machine with stone (obstruction) in point**.** Current signature of lock fouling is different from obstruction with stone. In the first case there is a low steady current for 2 secs. and then the current is raised due to lock fouled. In the second case of stone obstruction, the current rises within 1 sec. after operation started while the switches are not set.

Current signature for 220 mm throw Point machine for Thick Web Switch (TWS)

In 220 mm throw point machine for TWS, the function of Spring Setting Device (SSD) is to pull the open tongue rail away from the stock rail to provide sufficient gap. In the absence of SSD, the train moving on the stock rail may keep on hitting the tongue rails, transferring the impact to the ground connections which may bend and give failure. The operation of SSD alters the current signature of a TWS point from that of a normal point. This is shown in *Figure 30*.

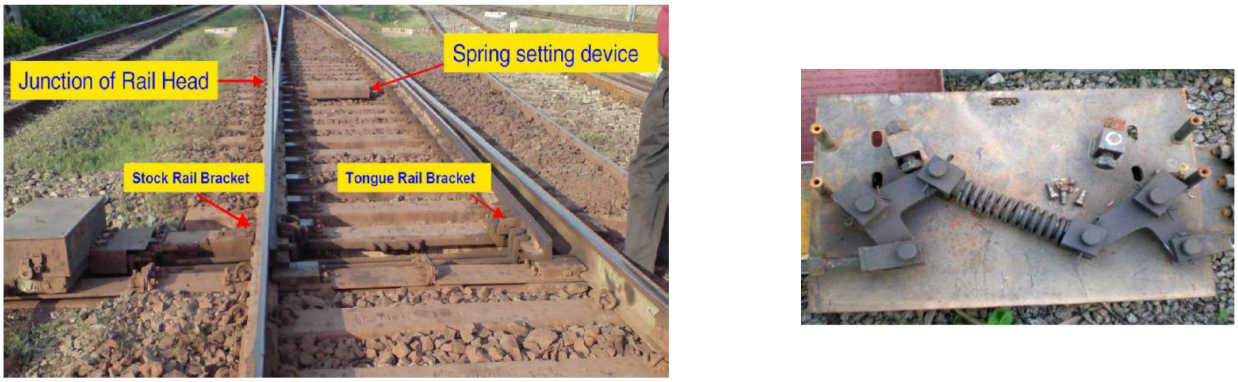


Figure 29: Layout of 220 mm throw point machine for TWS and Spring Setting Device

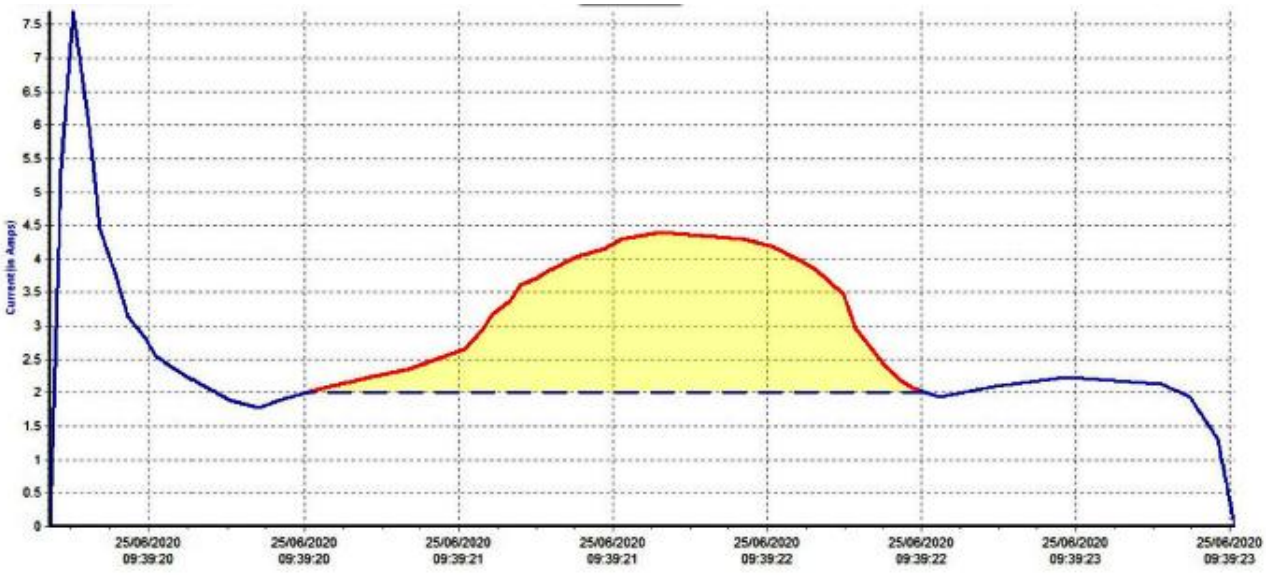


Figure 30: Current signature of point with SSD

Point HMU Alarms

Following type of alarms can be sent as SMS from test room with GSM modem for quick action by maintenance staff:

- *Point machine not operated* – Check control circuit in relay room
- *Point machine operated* – no need to check in relay room
- *Point machine not locked* – Check for obstruction/adjustment
- *Point machine locked* - Check detection circuit
- *Friction clutch requires adjustment*
- *Carbon brush worn out*
- *Effort required to operate point* – Gradual increase in current indicates – point requires cleaning & oiling of slide chairs.

Wiring of sensors

The voltage sensors are connected in parallel as shown in *Figure 21*. The current sensors are connected in series in the circuit. In *Figure 31* below, the current sensor is taken in return path and the wire through the sensor is taken without any electrical contact. Thus galvanic isolation is maintained between point operating circuit and the sensor. The current sensor measures N to R as well as R to N current.

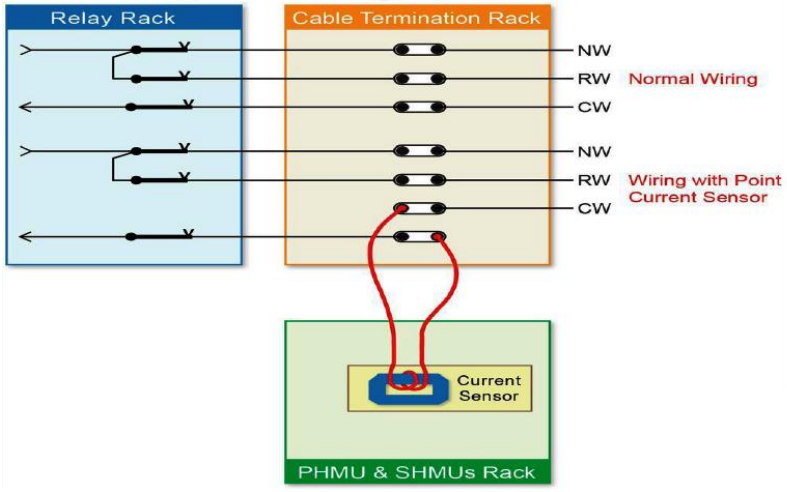


Figure 31: Wiring of current sensor

Possibilities of improvement

If more complex softwares are developed which can detect all the events precisely then this will definitely help in predictive maintenance of point and point machines. This can be achieved through Machine Learning.

4.4 DC Track Circuit Health Monitoring system

DC Track Circuit is the simplest of the track detection devices which are working on Indian Railways. It is comparatively less complex, its reliability is also quite good but due to its dependency on track and vulnerability to outside interference, the failures are more. Monitoring of Feed end current and Relay end current can provide useful alarms for MTTR as well as MTBF. This can be achieved through DC track circuit health monitoring system. This system consists of :

- Two current sensors to sense feed and relay end currents.
- One voltage sensing at feed end to sense battery/ supply voltage.

Since feed and relay are not located in the same location – two mini loggers are required to measure the currents.

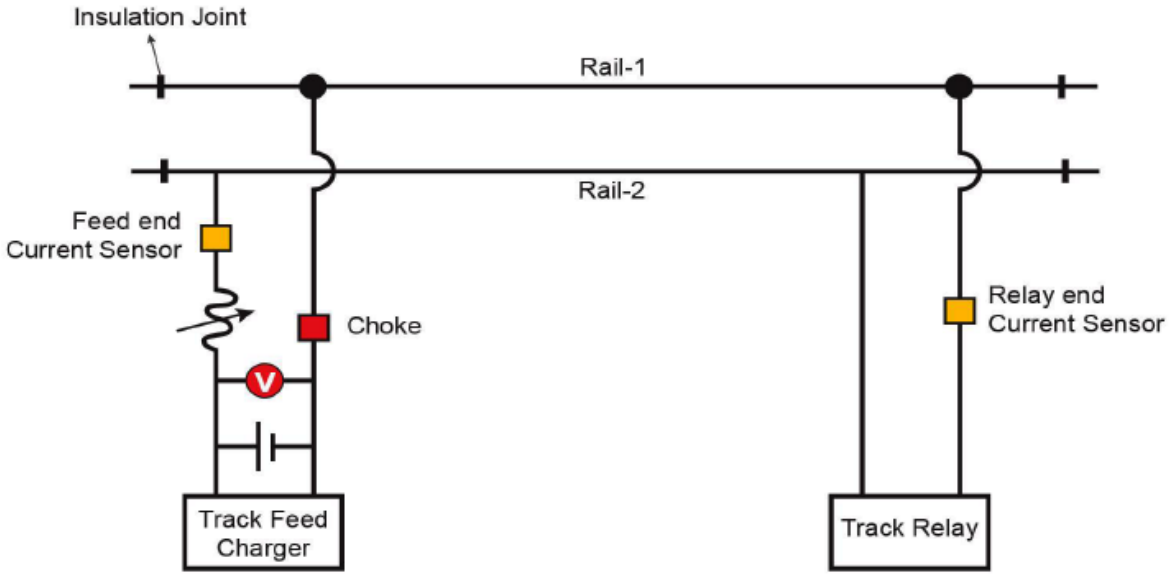


Figure 32: DC Track Circuit current sensing

Note:

1. Two current sensors are to be used for feed and other relay end.
2. Voltage across the battery is measured.
3. Potential free contact of Track feed charger is taken as digital input.

The typical current signatures of a DC Track Circuit for train occupancy and clearance are shown in *Figure 33*. Initially when the track is clear, the feed end and relay end currents are of the order of 200 mA to 300 mA. When the track is occupied by a train, the track is shorted by the wheel. The feed end current increases up to about 1 Amps. and after vacation by the train it comes to normal value. Similarly on occupation, the relay end current goes down to almost zero and after vacation it comes back to its normal value. The difference between the two is leakage current.

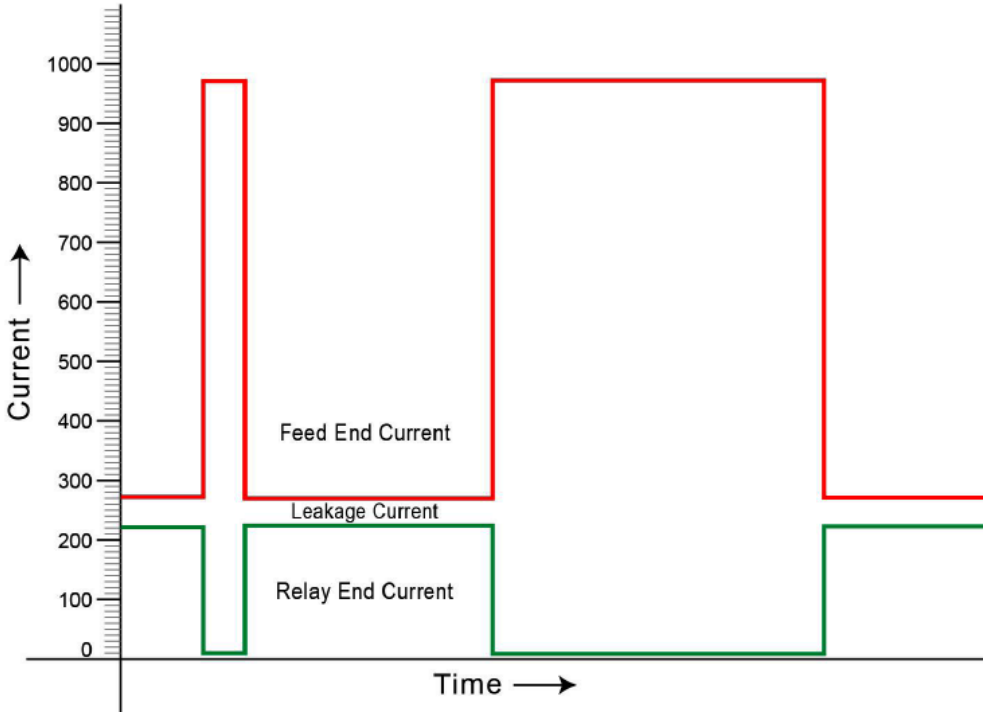


Figure 33: Current Signature DC Track Circuit

Parameters of a DC Track circuit

Minimum excitation of Track Relay should be 125% of pick up value to avoid failure.

Maximum excitation of Track relay should be 300% of pick up value to avoid unsafe side failure.

Upper and lower limits can be set as less than 150% excitation and more than 300% excitation to generate alarm and send SMS to the maintainer.

Feed end Current = Leakage Current + Relay Current

Monitoring of DC Track Circuit during rain

To monitor the behavior of a DC Track Circuit during rain, its current signature can be analyzed and the maintainer can be advised to go and check the level of water in track and for increasing the feed end voltage.

The typical current signature of two adjacent track circuits B9AT and B10T in a yard during rain are given in *Figure 34* and *Figure 35* Time is taken on X axis and Current is taken on Y axis. From *Figure 34* it can be seen that leakage current started increasing in B9AT as it started raining. It took almost 12 hours to come to normal. The leakage in B9AT is more as compared to B10T. Thus on analyzing the current signature, the maintenance personnel can decide which track circuit is to be attended on priority. In this case it is B9AT. This is how the maintenance can be made easy with the help of DC Track Circuit Health Monitoring System.

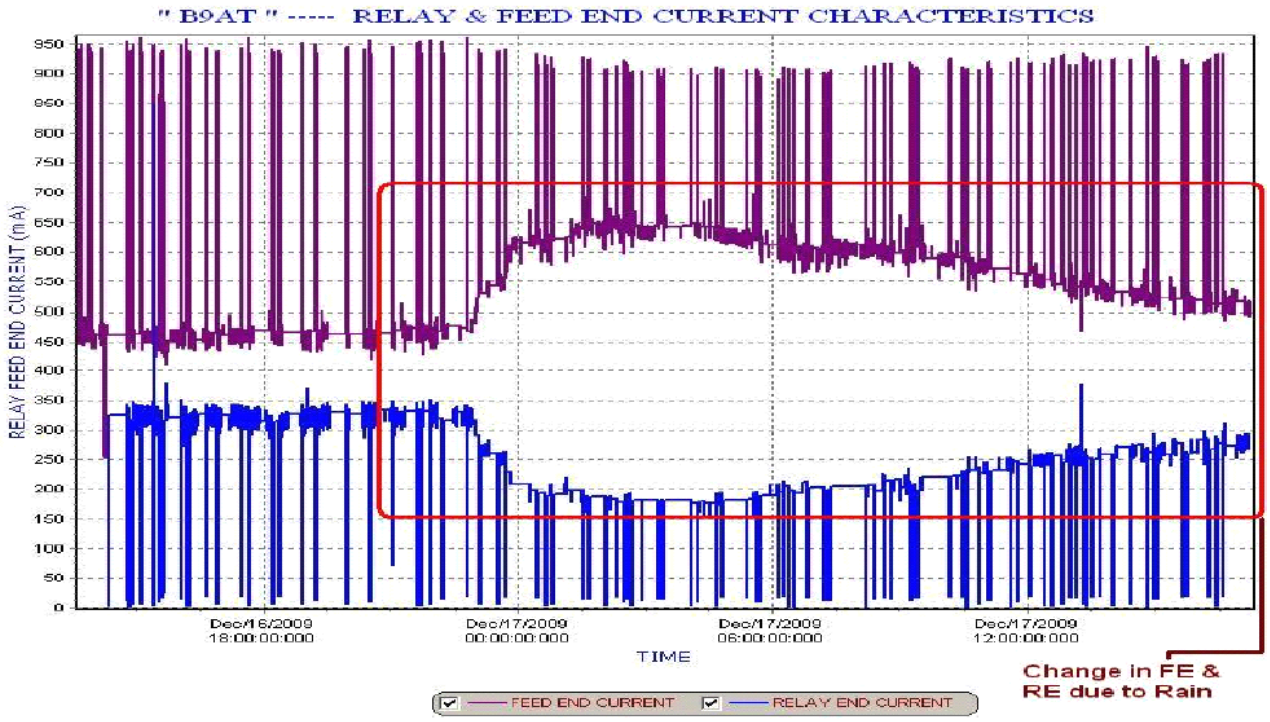


Figure 34: B9AT Relay end and Feed end Current characteristics

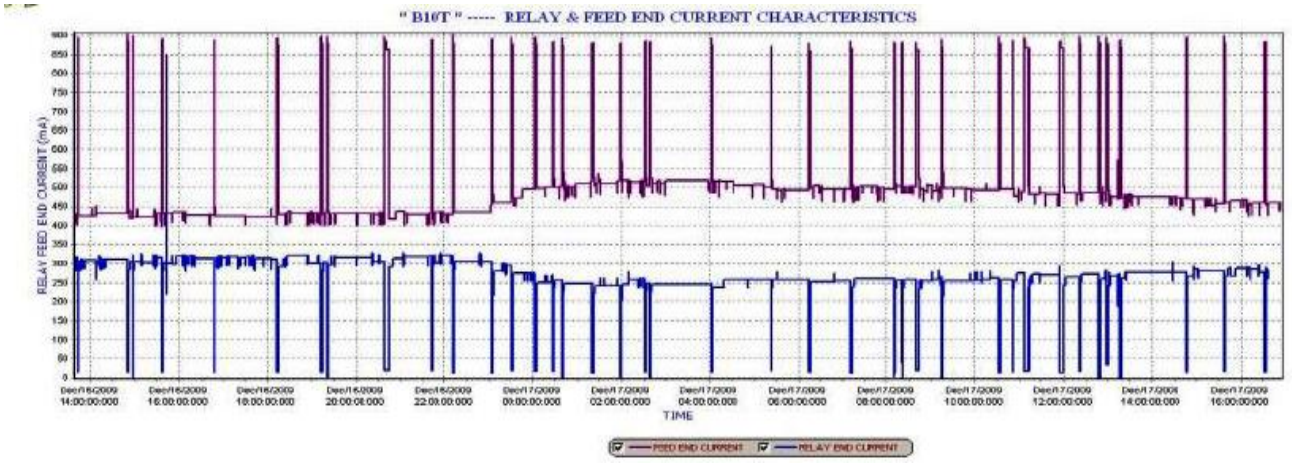


Figure 35: B10T Relay end and Feed end Current characteristics

DC Track Circuit HMU Alarms

Following type of alarms can be generated:

- *Relay end current beyond set limits*.
- *Leakage current more than set limit*
- *Feed end current less than set limit*
- *Relay end current decreased beyond limits* – with leakage current same – check for high resistance of bonding.
- *Relay end current decreased beyond limits* – with leakage current and feed end currents increase – check for low ballast resistance

4.5 Battery Health Monitoring Unit (BHMU)

The root cause of cell failure in a battery is that all cells in a battery bank are not equal, but battery charger treats all cells equally. The state of charge of all the cells may not be same but same current is going through the circuit is as the cells are in series. Thus a cell which is weak over a period of time becomes further weak and then ultimately fails. This can be found out with the help of Battery Health Monitoring Unit (BHMU).

Parameters monitored by BHMU

- Each cell voltage
- Temperature
- Battery charging/discharging current
- Load current



Figure 36: Battery Health Monitoring Unit

This system consists of both hardware and software –

Hardware – Battery health monitoring system to monitor 55 cells voltage, bank voltage and charge, discharge and load currents – along with battery backup and charger.

Software - Software is loaded in the CMU in the test room or the local PC if provided. Online graphical indication of each cell voltage can be seen remotely on the PC provided in the test room or supervisor's office

At the station by operating the key pad – each cell voltage and alarms generated can be seen [PC also can be provided at the station, if needed]

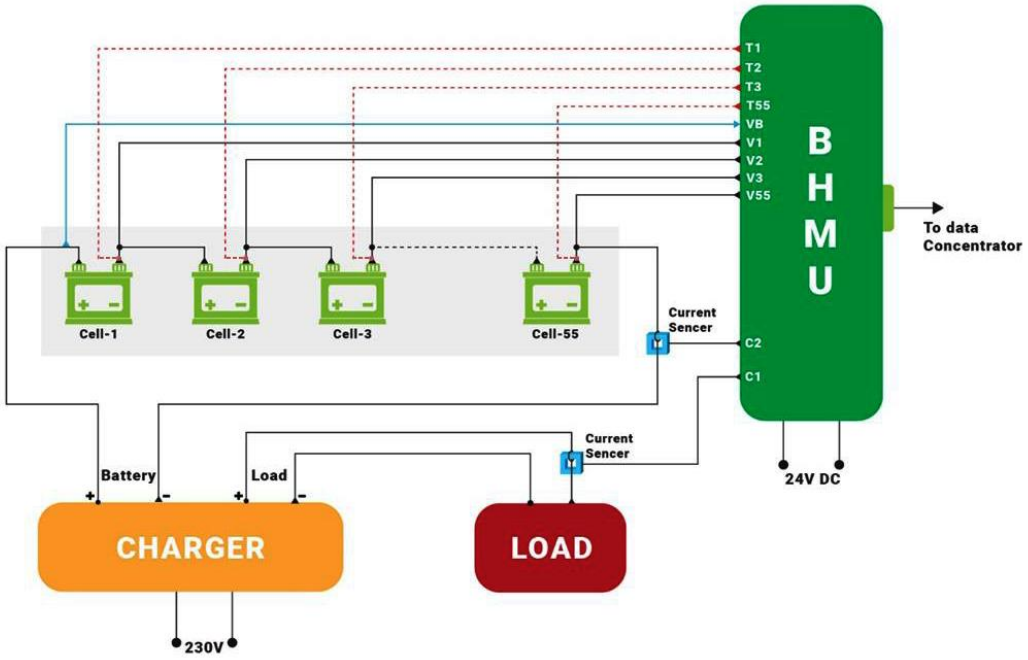


Figure 37: Arrangement of a BHMU

In the *Figure 37* above, arrangement for health monitoring of a battery bank of 55 cells is given. Two current sensors are provided, one to measure current coming in and going out of cells and the other one to measure current drawn by the load. T1 to T55 are ports for Temperature (connected by red dotted lines) and V1 to V55 are ports for voltage (connected by black lines).

BHMU alarms

From the test room online SMS can be sent to maintenance staff for quick attendance of failure. BHMU generates online alarms when any measured value exceeds set limits

- Cell voltage less than set limit
- Cell voltage more than set limit
- Bank voltage less than set limit
- Bank voltage more than set limit
- Charging current more than set limit
- Discharging current more than set limit
- Load current more than set limit
- Load current less than set limit
- Cell temperature more than set limit
- Cell temperature less than set limit
- Battery bank state of charge is less than set limit

In *Figure 38* below graphical analysis of a weak cell (cell no. 22) in a battery bank is given. Time is taken on X-axis and Voltage is on Y-axis. For each cell 1.4 V to 2.8 V is the band where the voltage varies for each cell at blue portion. The graph in red colour is the actual voltage of cell no. 22. Initially the cell voltage is about 2.1 V. At a particular time the AC power supply fails. The voltage starts slowly dropping and within one hour it becomes zero as shown in the first curve. When the power supply resumes, the voltage comes back to normal value. As seen in the graph, further there are power failures of short duration. The cell voltage has not become zero but dropped upto 1.2 V or 1 V. All these type of parameters can be found out with the help of BHMU.

During routine maintenance, it is very difficult for the maintainer to switch off the charger for 1 or 2 hours for testing, hence the continuous monitoring of the asset i.e the cell helps in finding out its health at any moment and appropriate action can be taken.

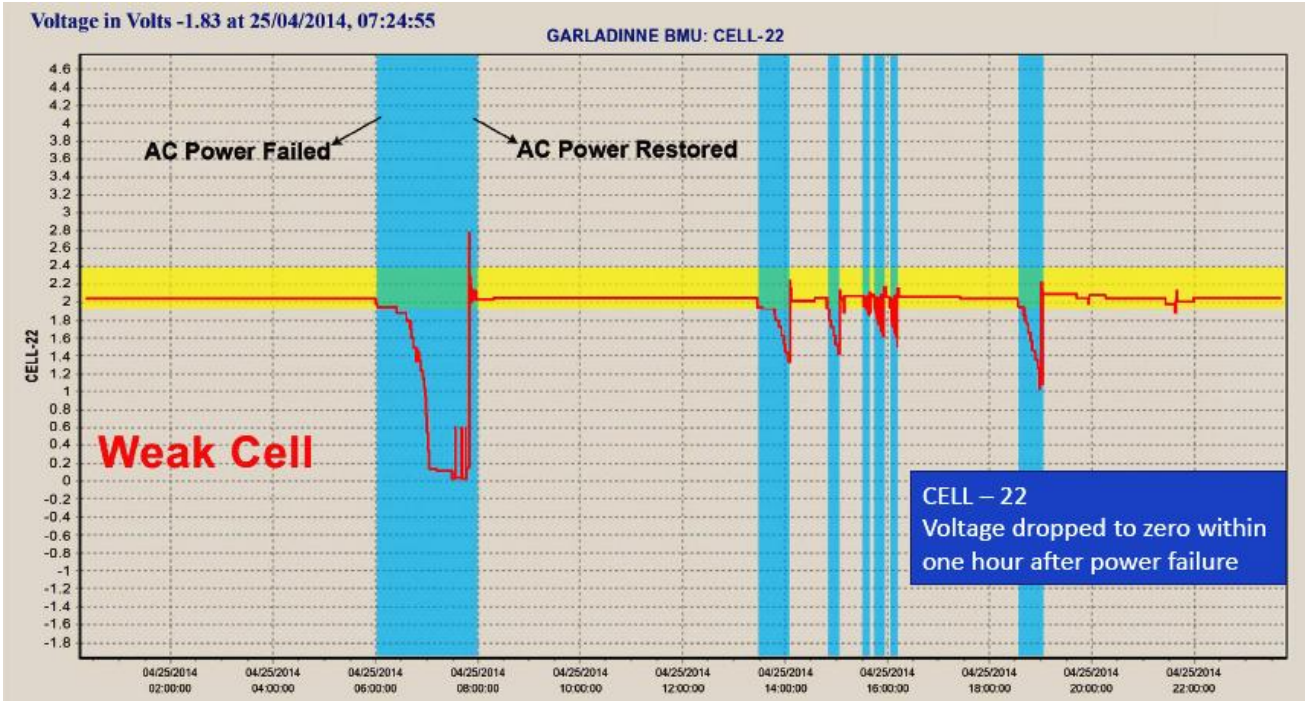


Figure 38: Graphical analysis of a weak cell

Another problem faced in a battery bank is the forming of high resistance at the terminals of a cell which is shown in *Figure 39*. Initially the voltage of cell no. 19 is 2.25 V and on failure of power supply for a period of 1 hour, it drops upto 1.4 V. When power supply is resumes, its voltage goes up much more than its normal value upto about 2.8 V. Here it can be seen that throughout blue portion, the voltage remains constant. It indicates that the cell is

in healthy state and ready to deliver the required current for about an hour. But the question arises that why there was a voltage drop? It is due to the high resistance of cell terminals. As we know directions of current change while charging and discharging. Due to this, same resistance is getting added for one direction and subtracted for other direction from the cell voltage. Thus we are able to find out cell terminal with high resistance.

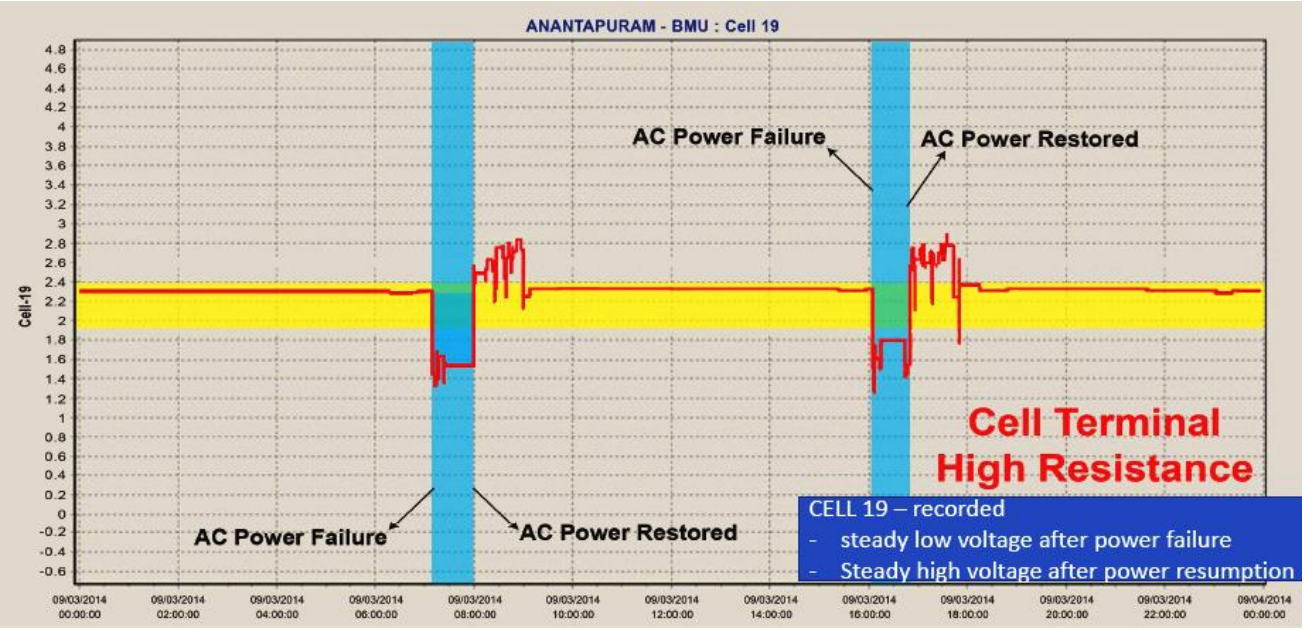


Figure 39: Graphical analysis of high resistance at the terminals of a cell

Purpose of BHMU

- To reduce MTTR as the root cause of failure is provided as alarm.
- To increase MTBF as the alarm is generated before failure of bank.
- Extending life of battery bank by selective replacing of weak cells found with the help of BHMU.

4.6 Axle Counter Health Monitoring unit (for SSDAC & HASSDAC)

HMU for SSDAC

In SSDAC system, the SSDAC units are installed near track and Reset box is installed at station. Vital Relay (VR) and Preparatory Relay (PR) are picked up in trackside SSDAC unit. Reset box sends the command to SSDAC unit and receives diagnostic data from SSDAC unit.

When VR and PR are dropped, there is no way to know whether axle counter is disturbed or occupied. But since it is an intelligent system, it is able to give diagnostic data through error codes. These error codes are available in the reset box, and the maintainer is not available round the clock near reset box to see these error codes when displayed. These error codes are made use in generating alarms for the maintainer in the following way:

- A Digital Axle Counter Interface has been developed which can take data from reset box. One DAC Interface can be connected to 8 reset boxes.
- Existing NMDL is suitably changed to process SSDAC diagnostic packets.
- SSDAC status can be seen through a PC connected to Data logger at station and also in Test room.
- It is possible to get diagnostic data of all the axle counter units through DAC Interface.
- Audio Visual alarm is generated by DAC Interface to call attention of Station Master in case of abnormality.
- The DAC Interface can be used for CEL and GGTronics make SSDAC which in turn is connected to Data Logger.

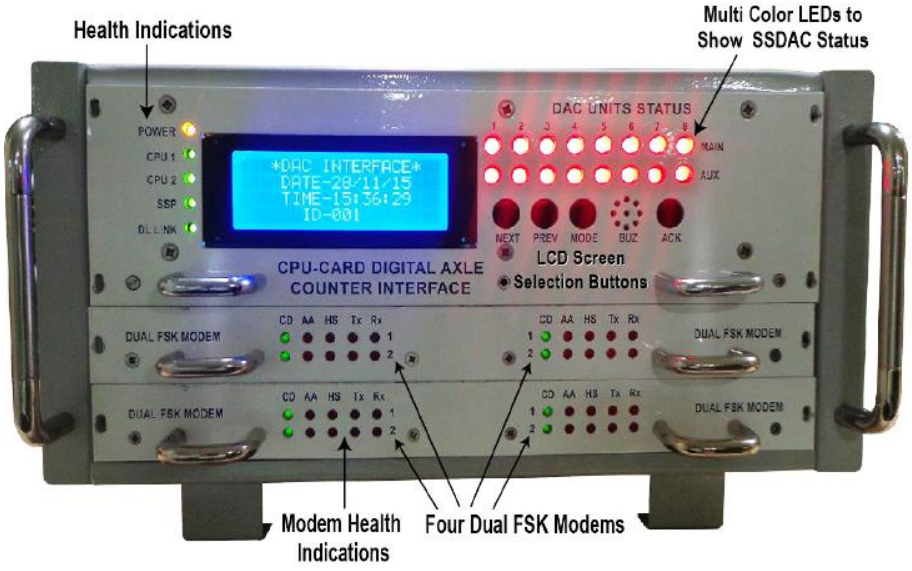


Figure 40: Digital Axle Counter Interface

An arrangement for BPAC between two stations using SSDAC is shown in *Figure 41* below:

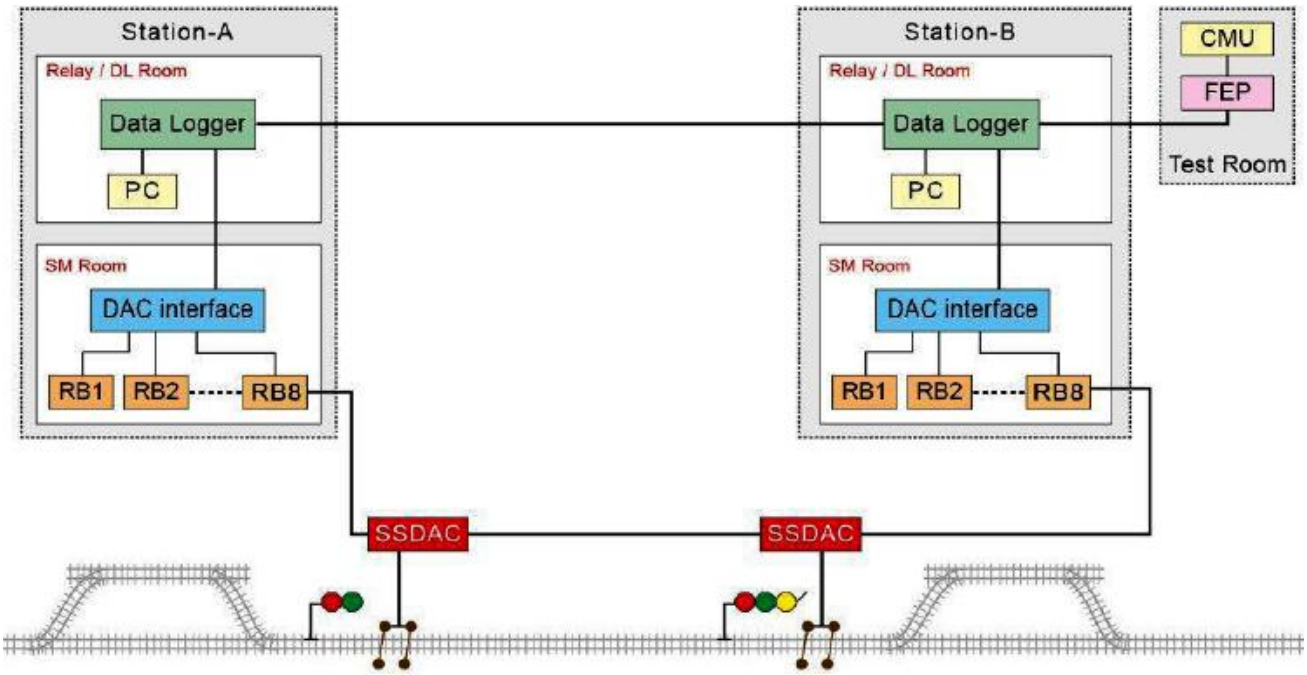


Figure 41: Monitoring SSDAC diagnostics from Test Room through Networked Data Logger system

Alarms

Alarms generated are sent in the form of SMS to the maintainer to take action. The error code numbers itself will not serve the purpose as these are not standardized**.** For example the logic (description) of error code no. 22 for CEL SSDAC is different from that of GGTronics SSDAC. Hence only error code is of no use to maintainer, instead along with error code description and action to be taken is included in the notification. Following is the list of alarms with their logics:

Table 1: Alarms & their logics

Sr. No.	**Alarm**	**Logic**
1	Error code number & description	Error code
2	Type of abnormal wheel	Abnormal wheel type
3	Wheel sensor health	Health of wheel sensor
4	Communication error	Direction Identification
5	Reset not applied within time	Reset not initiated by SM after error occured
6	Reset not applied by remote end	Reset applied at one end but other end not applied.
7	Reset failed	Reset applied but system not cleared.

Table 2: GGTronics - Error codes

Code	Action
01	Reinsert PD1 module and reset
02	Reinsert PD2 module and reset
03	Reinsert SM-CPU module and reset
04	Reinsert Modem A module and reset
05	Reinsert Modem B module and reset
06	Reinsert Relay Drive A module and reset
07	Reinsert Relay Drive B module and reset
08	Reinsert CPU module and reset
09	Check MS Coupler Comm link/Replace CPU1/Replace Modem
10	Check MS Coupler Comm link/Replace CPU1/Replace Modem
11	Check MS Coupler Comm link/Replace CPU1/Replace Modem
12	Check MS Coupler Comm link/Replace CPU1/Replace Modem

Table 3: CEL - Error codes

Code	Action
12	Replace MLB Card
13	Replace MLB Card
14	Insert all cards properly
15	Check relay and its connections
21	Replace MLB Card
22	Replace MLB Card
24	Insert all cards properly
30	Rectify communication
31	Check arrangement of detectors – at proper height. Replace card 1&2 if necessary.
32	Reset – if not rectified – replace MLB cards
33	Reset
34	Check entry end axle detector A. Check SCC1 card and replace.

Table 4: Advantages of SSDAC monitoring

Sr. No.	Incidence	Without SSDAC monitoring	With SSDAC monitoring	Benefit
1	Error code generated	SM informs to maintenance staff – delayed message	SMS message – which gives defective end	Reduction of failure time
2	While resetting – SM not pressed reset button properly	SSDAC does not change to preparatory mode – train enters section	Mistake of SM - received as SMS – staff advise SM	Reduction of failure time
3	Supervisor tries to access log of error codes – reset box	CEL SSDAC – old error codes -past 10 error codes only are available	All old error codes upto 100 with time stamp available	Better analysis
4	SSDACs of multiple vendors – error codes interpretation	Same number error code – meanings different	Root cause and action to be taken is sent as SMS to staff.	Reduction of failure time
5	Dual BPAC or HASSDAC	SM cannot repeat error code – reset box in relay room.	Maintenance staff gets SMS message	Prevents failure
6	Repeated failure of SSDAC – not able to identify root cause	OEM sends their service engineer with Laptop to get diagnostic data from location.	Diagnostic data (not just error codes) are made available at test room – same can be shared with OEM by railways	Better analysis

HMU for HASSDAC

- It is possible to connect DAC Interface with HASSDAC also.
- Combined Reset box is provided in the Relay Room so all the error codes can be seen by maintenance staff.
- Reset is applied to the faulty axle counter by the good axle counter automatically at combined reset box.
- Reset box in SM room is used to reset both the axle counters when both of them are faulty.
- Interface unit is provided on SM room which gives audio visual alarm to SM when any axle counter changes to error mode. It gives alarms like another end applied reset while SM did not.

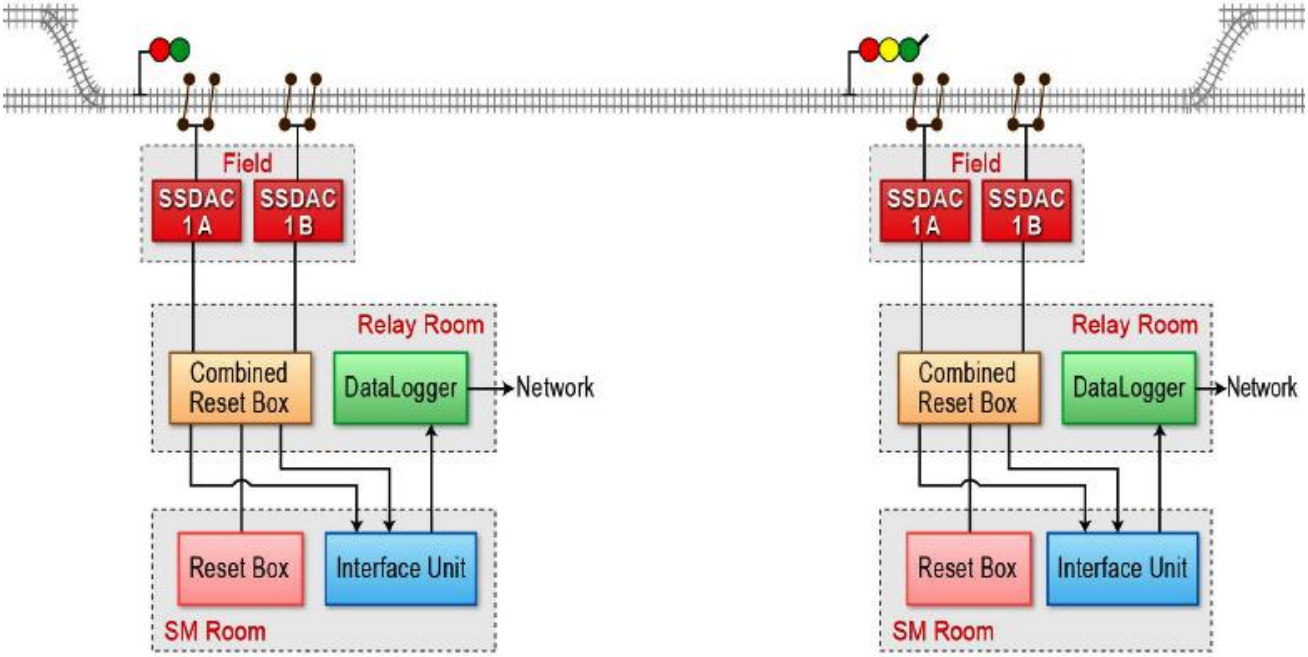


Figure 42: High Availability SSDAC Interface to Data Logger

4.7 Health Monitoring of Electronic Interlocking

To know about the problem in one of the modules/cards of an Electronic Interlocking system, its health data should be made available at the data logger.

Present system

The present EI systems whether of Medha, Kyosan, Microlok or WESTRACE do not provide health data. The diagnostic data is restricted to the respective Maintenance Terminals provided at stations which run only on specific software.

Need for health monitoring of EI

If the health or diagnostic data can be extended to data logger through any one of the ports of EI, then following types of alarms can be generated and brought to a central place:

- Input card failure
- Output card failure
- Communication of Input card failure
- Communication of Output card failure
- Processor card failure
- Communication between EI & operating PC failure

This feature has been provided in Alstom EI in certain section of Eastern Dedicated Freight Corridor (EDFC).

Some other approved firms have also developed systems for monitoring of Maintenance Terminal from a central location. A brief description is given below:

(i) Kyosan MTC - Centralized Management Systems

Kyosan has developed a Maintenance Console Terminal Centralized Management System for K5BMC Electronic Interlocking System which facilitates to monitor the Maintenance Terminal of individual stations from the centralized location i.e. Central Control room/Divisional head office.

Advantages of K5BMC Networking

- All stations can be monitored from Divisional office or Control room.
- MTTR (Mean Time To Repair) will be reduced.
- Troubleshooting and offline analyzing of failure is easy.
- Permanently OEM can establish access to the all Divisional Control offices to give 24X7 support.
- Ease of installation.

Kyosan Maintenance Terminal Console (K6MTC)

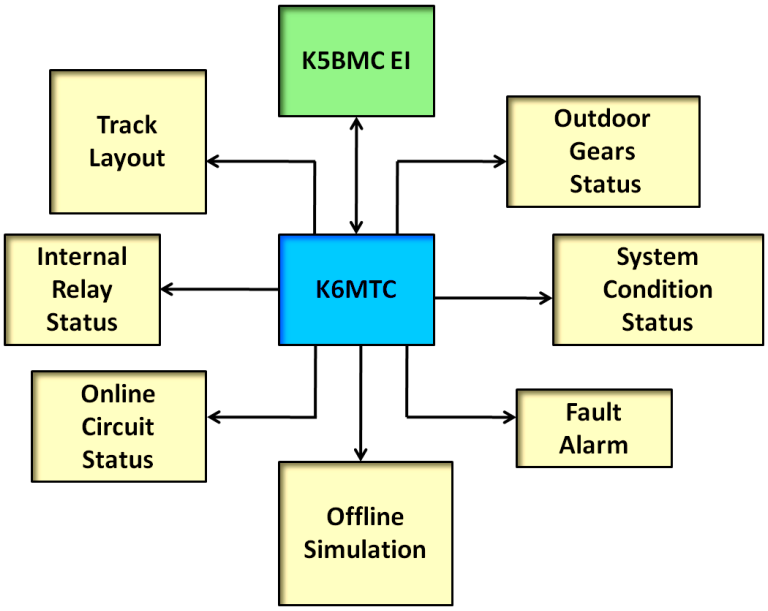


Figure 43: K6MTC Block Diagram

- K6MTC is a Kyosan make EI Maintenance Terminal Console.
- MTC provides ease of access to maintainer in maintaining the Electronic interlocking system.
- It facilitates both online and offline diagnosis.
- Maintenance staff can easily check data history on the screens and print it out to diagnose the condition of a failure, trouble and/or accidents.
- It has various display windows to monitor the functionality of EI system and troubleshoot in case of any failure in signaling systems.
  - Relay status display (Relay Library)
  - Station Yard layout display
  - System status display (System architecture view)
  - Timing chart display
  - Relay wiring display
  - Outfield (wayside) equipment display
- The MTC stores the historical data of
  - Electronic Interlocking system status,
  - Wayside equipment status,
  - Interlocking functionality data,
  - Train movement status etc.

Basic types of architecture

K6MTC System architecture can be configured,

- to monitor Single station from single central location
- to monitor Multiple stations from Single central location
- to monitor Single station from multiple central locations
- to monitor Multiple stations from multiple central location

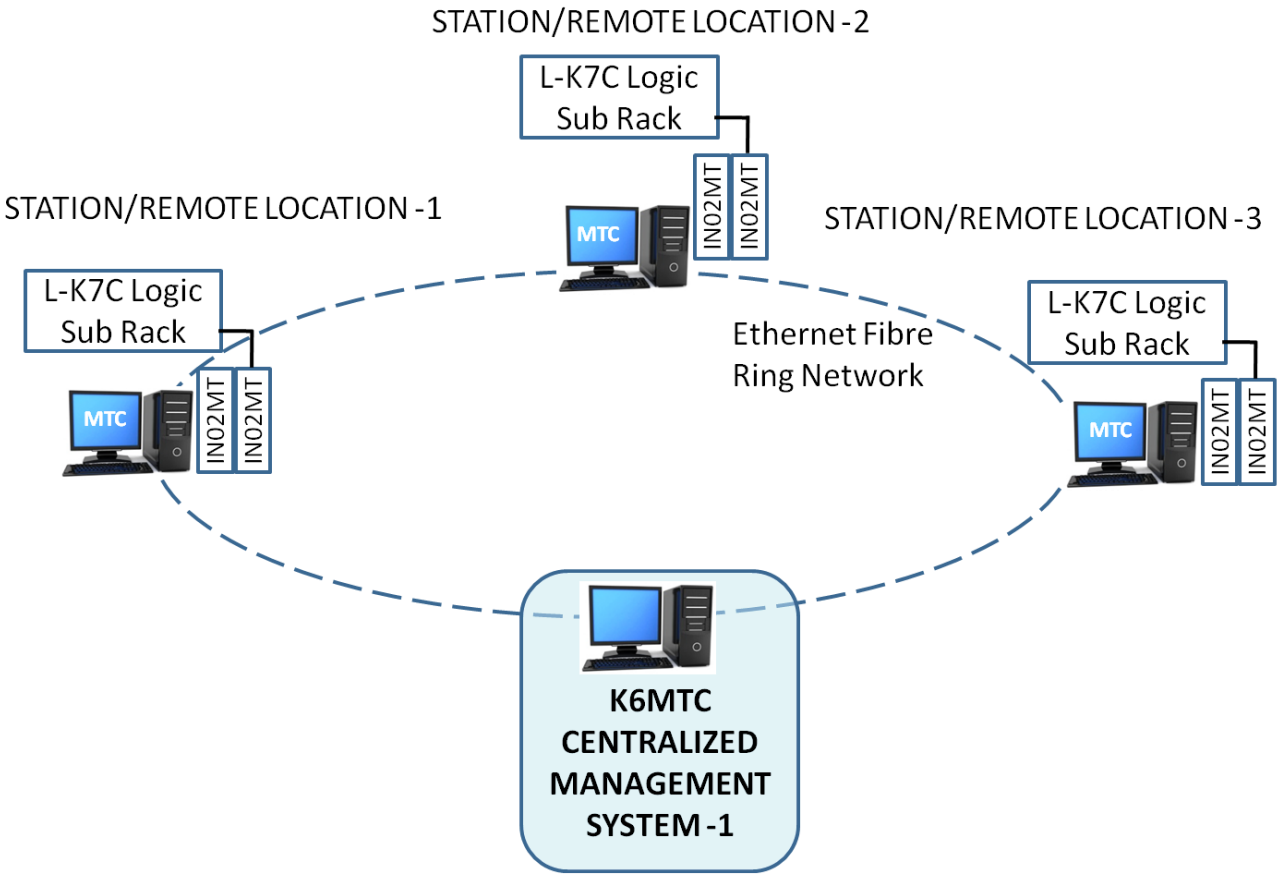


Figure 44: Multiple stations monitored from single central location

Features

- K6MTC Centralized management system facilitates Maintainer to monitor group of Stations or EI systems from a central location.
- Interface between MTC Station Equipment and Center Equipment is obtained by TCP/IP via Ethernet.
- K6MTC system from multiple stations are networked using fiber or wireless network.
- Failure details or reports can be downloaded from central location or station location.

- Interface between MTC Station Equipment and Center Equipment is obtained by TCP/IP via Ethernet.

(ii) Ansaldo STS Microlok II Electronic Interlocking

(Ref.: Ansaldo STS's letter no. M0 199/RDSO/MLK-II/0323 dated 16.07.2018 to RDSO)

Ansaldo STS (A Hitachi group company) has also indicated the possibility of networking maintenance related Microlok data to central location, subject to network connectivity at locations with at least 2 to 4 Mbps speeds.

Hardware requirements
At stations

(i) 1 Terminal server one at each location. (Example : Moxa CN26501 - 16 port). The model is driven by the number of Microloks in a location. One Microlok = 1 Terminal Server port.

(ii) 1 Industrial Server and 1 KVM if necessary. One at each location. (Example Moxa DA-820).

(iii) MDU Software.

At Central Location

(i) 1 PC at a centralized location (MAX RAM, Intel Core i7-3517UE Processor (4M cache, 1.7 GHz) for theV2406A-C7 series).

(ii) MDU software.

The topology

Each remote MLK system will have a unique IP address and shall be connected on the allotted VF channel in the telecom network.

Bandwidth

2 Mbps will be sufficient to connect about 15 MLKs, each MLK requires 128 kbps, and multiple 2Mbps will be required for more connections**.**

Software requirements

Existing MT software will not serve the purpose. A separate software application is already developed. New layout/software has to be created for each station to be networked.

(iii) Medha MEI633 Electronic Interlocking

Medha Servo have also developed MT-Networking with following features:

Central Server Application:

The Central application (Server) is just a monitoring software, where the events and faults of each station can be viewed. No operation of the yard shall be possible from this location. This application does not control the local MT application in the stations. The status of communication with all the stations will be displayed.

Client Application:

An additional client application (which is a separate SW application) shall be installed in Maintenance Terminal PC. This Client application sends all the data received from the CIU, to the central Server.

Connectivity:

All the station MT PCs shall be connected with the Server in the central location, in ring fashion on a railway network (E1/dedicated Fiber).

Network Requirements:

The bandwidth requirement will vary with the size of stations connected. Typically E1 would be sufficient.

Dedicated network is preferred as the protocols of all EIs are different.

Additional Hardware Requirements

Sr. No.	Item Description	Description	Remarks
1	Network Switch	Industrial grade Managed Switch	At each station and central location
2	Server	Xeon Server	At the central location for the Central Server SW
3	E1 to Eth converter or Dedicated Fibre to Eth Converter	MROTECK or any other	For connecting to the MT PCs
4	Cables	OFC and CAT 6e cables for connectivity	--

4.8 Signal Lamp Health Monitoring Unit (SHMU)

Failure of LED Signal lamp is due to the problem with the electronics inside the LED or example capacitors, ICs and other equipments provided with LED lamp. Once these are affected, the behavioural changes cause the changes in current. These can be delayed current or initial rushing through of the current and then stabilizing. These all bring unhealthy behaviour of the current regulator.
With the help of Signal Lamp Health Monitoring Unit (SHMU), we can set upper and lower limits of the current for operation of LED lamp. If the current is drawn beyond the limits, alarms can be generated

An arrangement of PHMU is given in the following *Figure 45* in which a current sensor is provided in the path of lamp circuit.

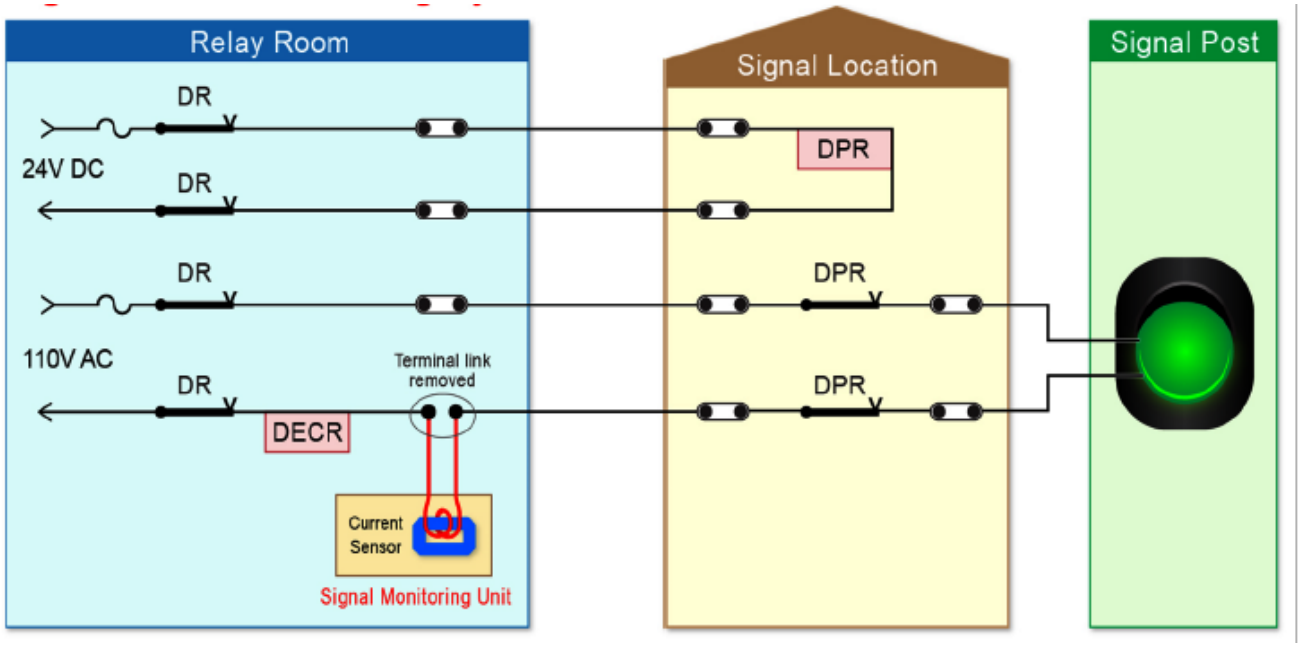


Figure 45: Arrangement for Signal Lamp Health Monitoring Unit

The following alarms can be generated by SHMU:

1 Current drawn by signal lamp is beyond limit –more than 160 ma / less than 100 ma.

2 Signal lamp drawing current when lamp control relay down.

3 Signal lamp drawing current but lamp checking relay not picked up.

4 Signal lamp not drawing current but lamp checking relay picked up.



Figure 46 : Signal Lamp Health Monitoring Unit actual view

4.9 Integrated Power Supply Health Monitoring Unit (IPS HMU)

Integrated Power supply is another processor based system. Its modules has built in processors and standby is available for each module.

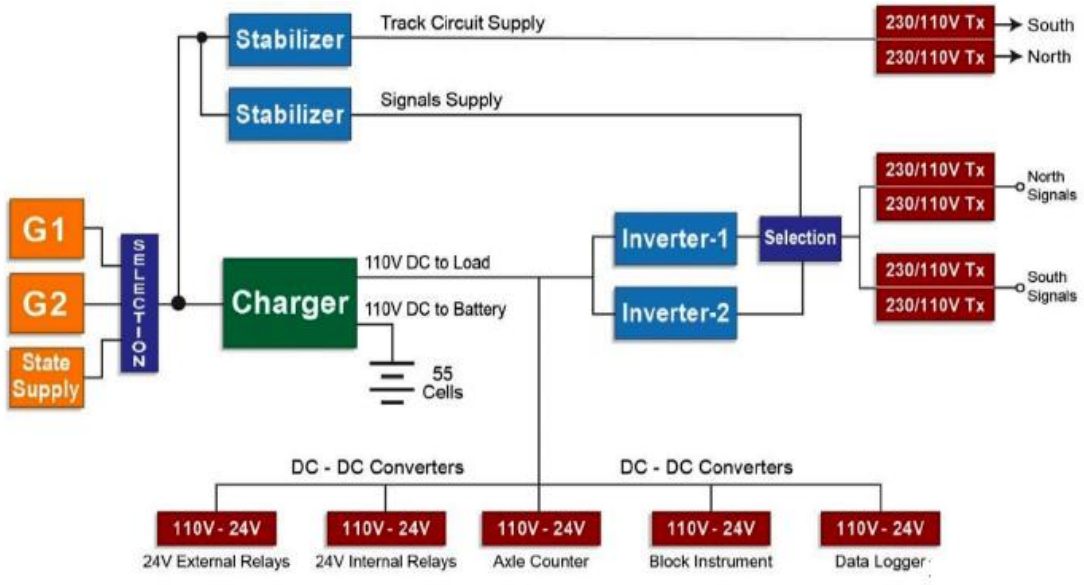


Figure 47: Integrated Power Supply System

There is already a provision in the IPS to give following type of digital alarms:

- Inverter 1 Fail
- Inverter 2 Fail
- Inverter 3 Fail
- Inverter 4 Fail
- DC -DC Converter Fail
- Mains Fail
- Call S&T Staff Battery Low (50% Deep discharge)
- SMR Fail etc.

But there are other problems in IPS like

- Failure to share the load
- Rise of temperature
- Failure to change state of charging FLOAT -BOOST
- Other system failures - as designed by OEM

The IPS can also give the alarms of above conditions with the provision of IPS HMU.

4.10 Air Conditioner Health Monitoring Unit

Relay room or EI room consist of sophisticated equipments with electronic components, like PCBs, motherboard etc. which are sensitive to temperature and dust. Normally Air Conditioners are provided in these types of installations and failure of these may affect the functioning of signalling circuits. To pre-warn about the failure conditions of Air Conditioners a Health Monitoring Unit (ACHMU) has been developed. ACHMU can monitor certain parameters and can generate alarms for action in right time.

ACHMU monitors:

- Air Conditioner supply voltage.
- Current drawn by AC.
- Temperature of the room

Following alarms can be generated by ACHMU:

- Room temperature beyond limits –Power failed
- Room temperature beyond limits –Power OK –AC not drawing current
- Room temperature beyond limits –Power OK –AC power ON [drawing current]



Figure 48 : Air Conditioner Health Monitoring Unit actual view

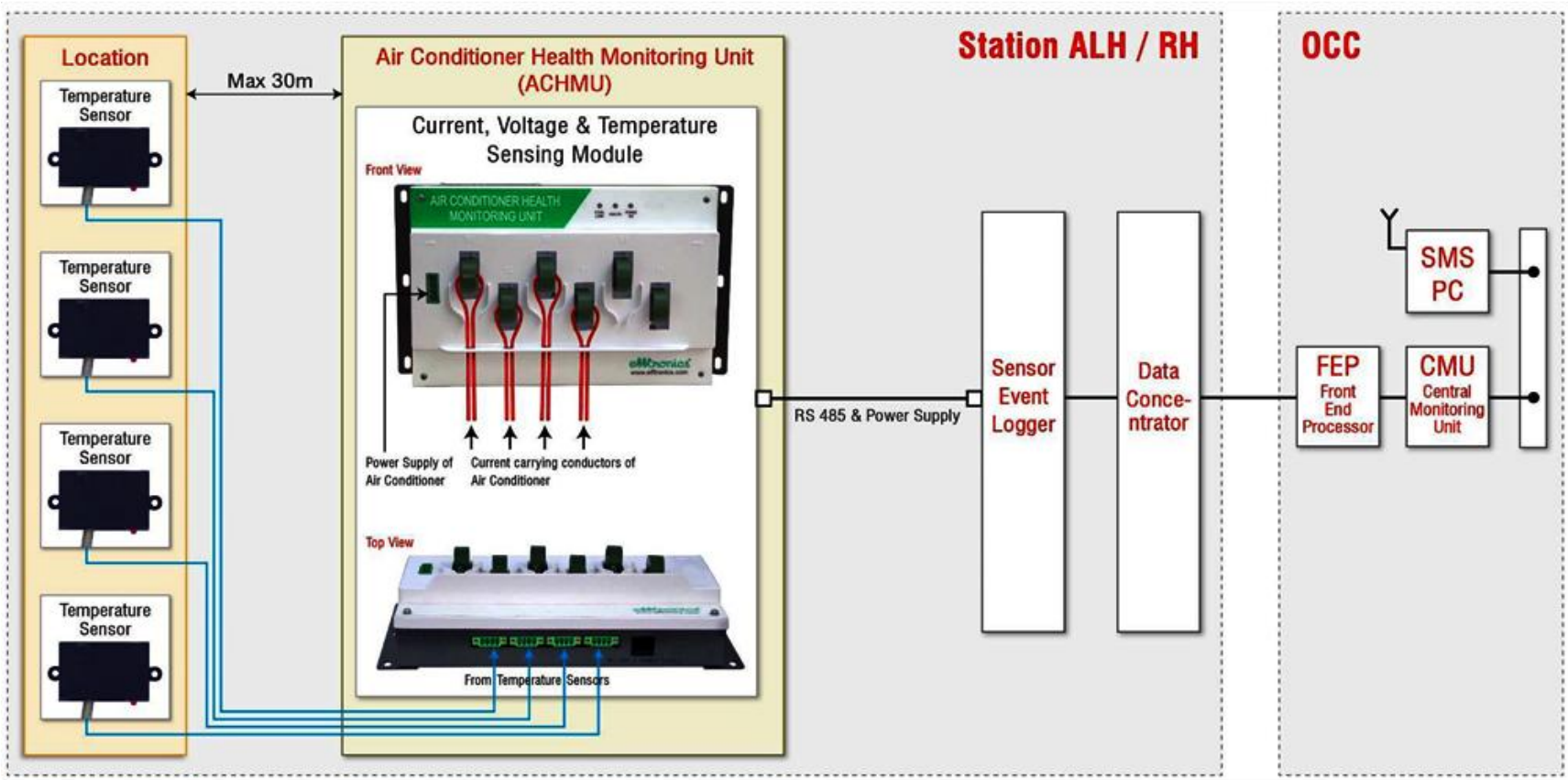


Figure 49 : Arrangement of ACHMU

4.11 Safety Point Alarm Unit

Failure to set points against occupied line:

On 19thJULY 2010, Uttara Banga Express collided with rear end of Vananchal Express as it was leaving the platform– 66 people died, 165 injured

Primary responsibility - Uttara Banga driver passed home at danger

Secondary responsibility –Sainthia SM failed to set the point against the occupied line of Vananchal Express –after its arrival as per GR

To prevent such accidents, a Safety Point Alarm Unit has been developed.

As soon as the train arrives at the station, if SM fails to operate points against the occupied line, this unit gives alarm within 2 minutes to alert him.

If within 3 minutes, he does not alter it, a normal fault logic triggers in the data logger system.



Figure 50: Safety Point Alarm Unit

Chapter V

Concept of Incidence Management through Analytics

5.1 Present system of Alarm dissemination

In the present system of alarm dissemination, signal failure alarm is conveyed automatically by Data logger system to maintenance staff through SMS from Signal Control Office/Test room.

Dissemination of Alarms

Alarms have been classified as given below:

1. Prioritization
2. Escalation
3. Collaboration

On the basis of priority, there are 4 levels of alarm:

Table 5 :Levels of Alarm

Sr. No.	Level	Criteria
1	P1	Incidence caused stoppage of traffic. Incidence which causes safety infringement. (Unsafe side infringement of safety, accident has not occurred but it is unsafe)
2	P2	Incidence causes stoppage of traffic if not rectified in few hours. (Example: IPS Mains supply fails and it is working on battery. If it is not attended in say 4 -5 hours, it may cause failure)
3	P3	Incidence which indicated deviation in equipment/System parameters which is likely to cause failure in future. (It indicates a deviation from normal working and it can cause the failure for example loose packing of the point which may not supposed to be attended on priority)
4	P4	Miscellaneous incidences (Statistical) (Examples: How many times the point failed or how many times the power supply failed/interrupted in a specified period?)

The system of reporting is also divided into 4 levels:

Table 6: Levels for System of Reporting

Sr. No.	Official	Role
1	Maintainer	Action - Hands on rectification of failures
2	Supervisors Level 1 & 2	Delegation - Takes responsibility to delegate to other maintainer in case the regular maintainer fails. Sometimes, he himself may attend and rectify the failure.
3	ADSTE/DSTE	Monitors - Guides - Ensures failures are rectified without delay.
4	Sr. DSTE	Information - Personally looks at failures with big impact on train running or safety related alarms.

Figure 51 below shows the escalation matrix for the details given in Table 6:

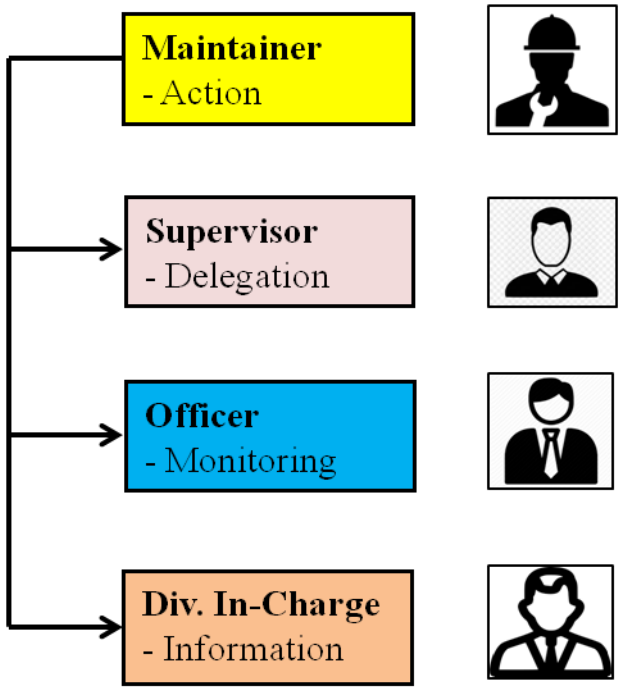


Figure 51: Escalation Matrix

The above Escalation matrix should be implemented in the messaging system to take appropriate actions during failures.

5.2 Proposed improvements in present system

App for notification of Alarms

An App is being developed which shall give notification as well as scope for monitoring the rectification of gear. For example, a maintainer receives a notification then there are following possibilities:

- He may be away from the station, or
- He might not have proper tools or material at the time of failure message, or
- He may be on leave, or
- Any other reason for not able to attend the failure.

In that case, the message can be transferred to the other persons.

Following are the features of notification app:

(i) Notification of selected alarms to selected personnel.
(ii) Monitoring of rectification of failures with collaborative working among all personnel.
(iii) Generation of reports which brings out system deficiencies in failure rectification – to improve the process of failure rectification.
- Delay in notification
- Delay in reaching the site
- Delay in rectification

For example, the reports can give information like:

- How many times the failure occurred in the last month?
- How the maintainer responded to the failure?
- Is the time taken to inform the maintainer is more?
- Is the travel time for attending a failure is more?
- Is it worth to keep the headquarters of maintainer at the current place?

Decisions based on above reports can be taken to minimize the time for rectification of failures.

Troubleshooting guidance by Supervisors to technicians in the station
The following setup is proposed for troubleshooting guidance to the maintainers at station:

1. Signal Supervisor at Divisional Control office
2. Maintainer at station
3. Signal Supervisor at SSE Office.
4. OEM Engineer at OEM office.

All the four together shall be able to see the diagnostic data on real time basis and then act on that collaboratively to reduce the MTTR. This system has to be followed in implementing predictive maintenance.

5.3 Incidence Management Centre

The current scenario in the Divisional Signal Control office (Test room) is such that there are too many monitors and display of information but it is not possible to look simultaneously to all and take action immediately. For improvement in the setup, a concept of Incidence Management Centre in the form of Operation Control Centre (OCC) in the present Test room has been proposed by M/s Efftronics System Pvt. Ltd., Vijayawada. The proposed arrangement is as shown in *Figure 52*
The OCC at the Test room shall have six agencies:

(i) Level 1 Supervisors in Test room
Persons at this level shall confirm from controller and ensure that the failure message is delivered to the maintenance staff. If the alarm is not generated by any HMU then they shall talk to OEM of HMU and co-ordinate with the maintenance staff.

(ii) Level 2 Supervisors in Test room
Persons at this level shall be professionally competent who will be in touch with the Site Supervisors and maintenance staff and guide them. They will have all the technical documents related to the equipments at site. They can contact OEMs of the Assets (Actual equipments like Axle Counter, LED Signal etc.), Signal Supervisor at Test room and the field staff. All the three together shall be able to put right the system in a less time.

(iii) OEM of HMU - To ensure correctness of incidence notification/Alarm.

(iv) OEM of Assets - For technical guidance/attendance of actual equipment at site.

(v) Maintainer at site - For attending the failure.

(vi) Signal Supervisor in the field - Responsible for guiding.

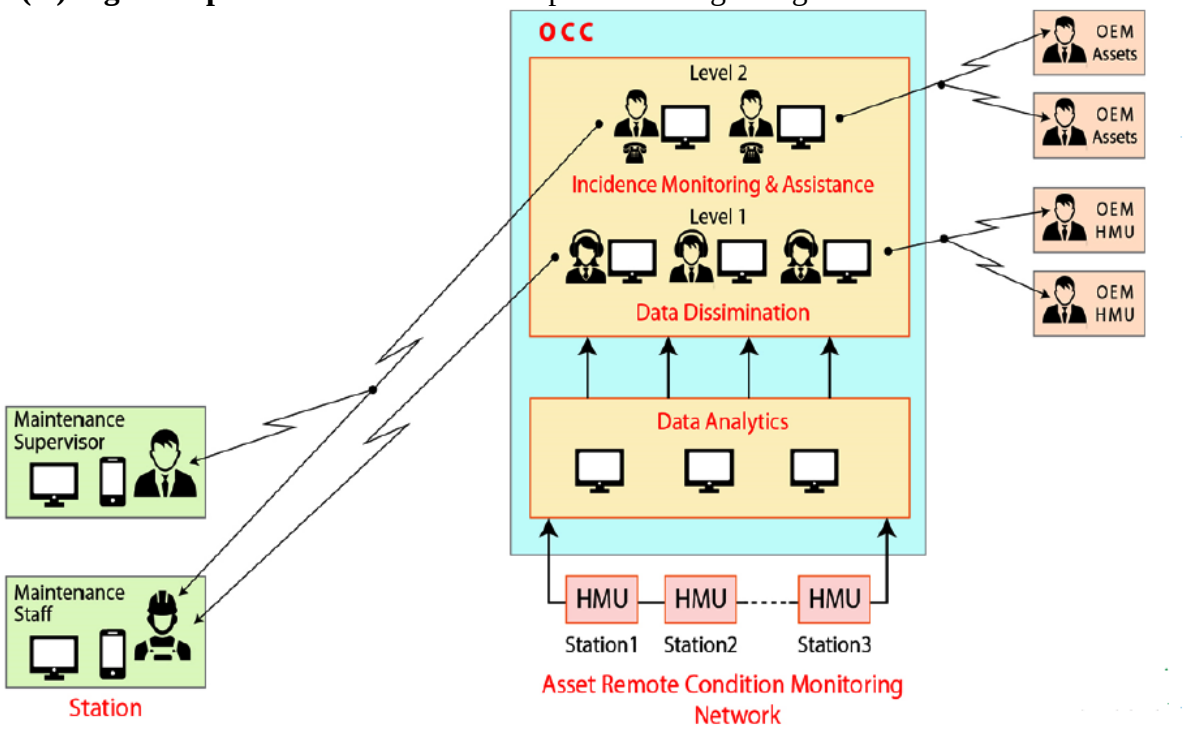


Figure 52: Set up of proposed Incidence Management Centre

Chapter VI
Remote Diagnostics & Predictive Maintenance

6.1 Introduction

Remote Diagnostics and Predictive Maintenance is a new concept for Signalling in Indian Railways. A draft specification (No. RDSO/SPN/RDPM/2020 -Initial draft) has been prepared by Signal Directorate RDSO which contains the functional requirement for Remote Diagnostic and Predictive Maintenance (RDPM) System for Indian Railway Signalling equipment using IoT based data acquisition systems and Machine learning/Artificial Intelligence. This initial release of Specification is meant for development of system together with initial trials and further improvisation based on the experience will be done in the course of time. Hence, the scope of this specification is to standardize the requirements for ensuring conformity and interoperability such that data being collected on any platform/IoT device shall be utilized for machine learning/AI based data processing in the system.

Note:

The draft specification (No. RDSO/SPN/RDPM/2020 - Initial draft) on RDPM being a new concept, is being circulated to all stakeholders (Zonal Railways, RDSO approved firms and interested industry partners) for their comments. Since the draft specification is an internal version of RDSO for the system under development stage, hence it is not to be used elsewhere.

The objective of providing Remote Diagnostic and Preventive Maintenance system is to assist maintenance team in taking appropriate maintenance action in advance to prevent the failure of signalling gears. At functional level the system is broadly divided into two stages:

Remote Diagnostic

Remote Diagnostic of equipment to reduce MTTR and providing aid to maintenance staff in rectifying the signal failures. This is achieved by automated analysis of parameters of Signal gears collected remotely using IoT devices. The system shall be able to give probable cause of failure to aid the maintenance staff for early restoration reducing MTTR.

Predictive Maintenance

Facilitating predictive maintenance by advance computing of Big data using Machine Learning and Artificial Intelligence. The data of all the stations shall be continuously analysed by system for developing the supervised and unsupervised machine learning. The system shall be able to send automatic alerts for Signalling gears which are likely to fail based on the system learning. This will assist the maintenance staff to take necessary action to eliminate failure before it occur.

6.2 System architecture

The system consists of the following:

Data acquisition for parameters of Signalling equipments using additional sensors and/or inbuilt diagnostic ports of the equipment. Details are given in Section 6.3.

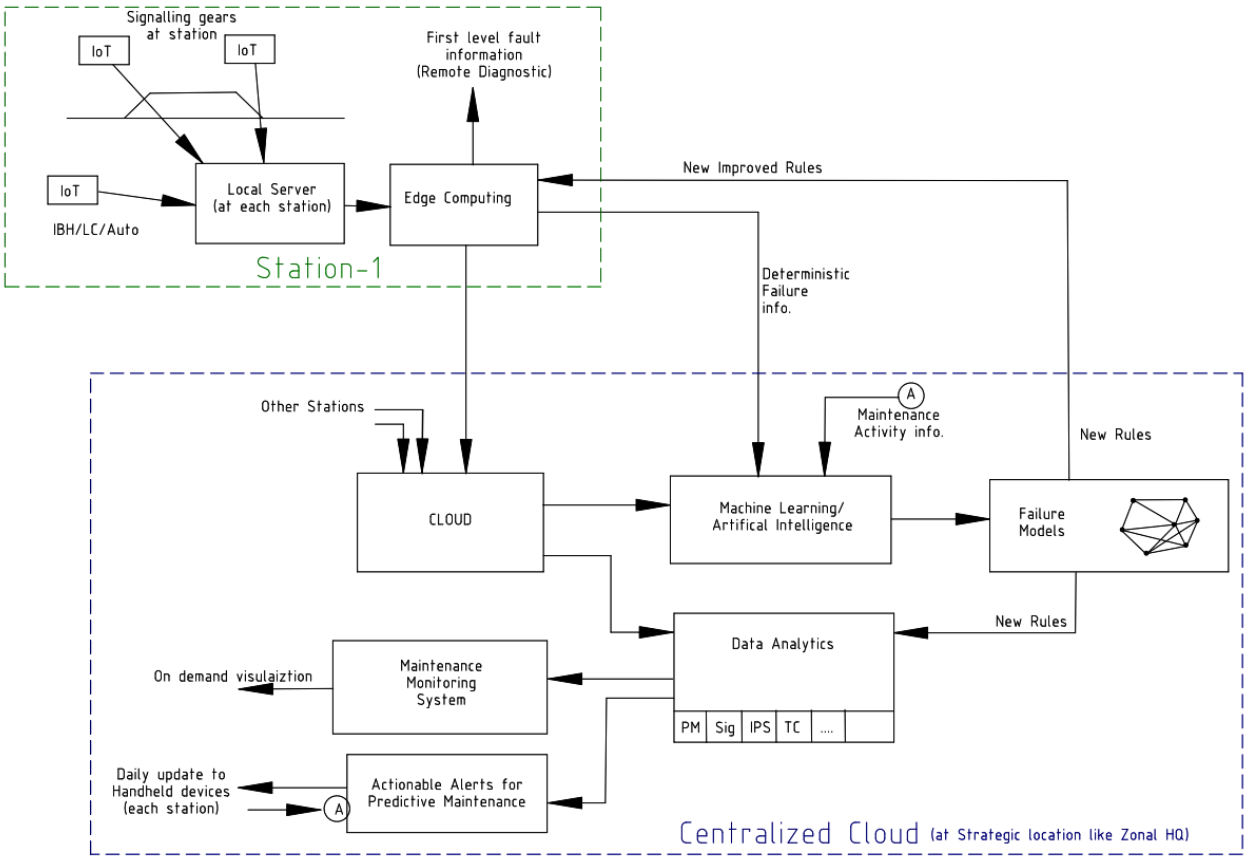


Figure 53 :Remote Diagnostics & Predictive Maintenance System Architecture

Transfer of raw data from site using IoT devices to local server at station. (Refer Section 6.4).

The local server is complemented by Edge computing device to generate first level fault and diagnostic information based on the realtime data.

The data from local servers at every station will be sent to centralized cloud. This data complemented by historical data and trends will be processed using advance computing through data analytics (Artificial Intelligence / Machine Learning) to anticipate any issues or failures before they occur.

Remote monitoring: An automated alert mechanism will send information to Signal Control of concerned Division and the concerned maintenance staff over SMS/Mobile app.

Predictive Maintenance: Mobile app will also be developed which shall be having realtime update on each station gears. The maintenance staff of particular station will be having the handheld device where at the start of each day he can see which gears need the specific attention for maintenance.

For critical faults, the SMS or automated voice calls may be provided once machine learning is stable and alerts are quite accurate (upto > 60%).

6.3 Data acquisition

The data from each signalling gear at the station shall be collected on realtime basis using the inbuilt diagnostic ports of the signalling gears and/or the external sensors.

6.3.1 Outdoor gears

Signals

The following data shall be recorded for each aspect of Signal:
i) AC Current.
ii) AC Voltage.
iii) Illumination of aspect.
iii) Status of local signal control/detection relays at Location boxes.

Points

The following data shall be recorded for each end of the Point:
i) DC operating Current.
ii) DC operating Voltage.
iii) Vibration.
iv) Status of local point controlling/detection relays at Location boxes.

DC Track Circuits

The following data shall be recorded for each Track Circuit:
i) DC feed end and relay end voltage.
ii) DC feed end and relay end current.
iii) Track relay position.
iv) Track charger potential free contact (or output voltage where PF contact is not available)

Axle Counters

Diagnostic data from Diagnostic port of Axle counter evaluator shall be captured through data port. This shall be based on recommendation of different OEMs of Axle counters of different makes.

AFTC

Diagnostic data from Diagnostic port of AFTC shall be captured through data port. This shall be based on recommendation of different OEMs of AFTCs of different makes.

Level Crossing Gates

The following data shall be recorded for each Boom:
i) AC/DC operating Current of Electrical Lifting Barrier.
ii) AC/DC operating Voltage of Electrical Lifting Barrier.
iii) Status of open close position for each boom

6.3.2 Indoor Gears

Some equipment data like status of relays, IPS PF contacts, etc is already available in existing Data loggers installed in relay room.

Relays

Status (pickup or drop) of each relay in the relay room shall be recorded.

Electronic Interlocking

Data from Diagnostic port of Electronic Interlocking.

Integrated Power Supply IPS) / Battery Charger
The following shall be monitored:
i) All voltage outputs
ii) Health of IPS modules from potential free contacts
iii) Availability of standby input power supplies from Auto-changeover system of IPS.

MSDAC
Diagnostic data from Diagnostic port of MSDAC evaluator shall be captured through data port. This shall be based on recommendation of different OEMs of MSDAC of different makes.

Surge Protection Devices
The potential free contacts of SPD devices where available shall be monitored. Care should be taken to keep sensor wiring from SPD such that (electrically) dirty cable in SPD box is not in parallel to sensor wires.

OFC Cable
Monitoring of Dark Fibre for monitoring the health of OFC cable, especially those not under NMS monitoring (like OFC for distributed EI, EI to SM room, etc). The dark fibre of the cable shall be used to detect the following:
i) OFC cut and Geographical Location of Cut.
ii) dB Loss / Degradation.

Fuse Auto changeover system
Status of main and standby fuse.

Battery
The health of battery to be monitored by using time proven techniques available in other industries using IoT.

Earth Leakage Detector (ELD)
Status of earth leakage from the ELD to be monitored.

Cables
The use of coordinated data shall be made by the machine learning to monitor the voltage drop analysis for checking the health of signalling and power cables. Hence, existing data collected from voltage in IPS room, Voltage in field, ELD data etc will serve for the health of cables.

Block Instruments
Line current and selective data for different types of Block Instruments using non-intrusive sensors.

UFSBI
Relay status and Potential free contacts of UFSBI modem, Data from Diagnostic port, etc shall be monitored.
The information already being logged in conventional Data logger shall be used.
All Networking switches/dc-dc convertors and other devices having potential free contacts for monitoring.

Ambient Temperature and humidity of Battery room, relay room, power room, IoT devices location, etc shall be recorded.

6.4 IoT device

The IoT device shall be software embedded system preferably COTS (commercially off the shelf) and will do the basic function of capturing the parameters from the Signalling devices using the sensors and diagnostic ports and transmit the data to Local Server through Gateway at the station. To ensure that the interoperability between different manufacturers, the protocols of EULYNX standard for Diagnostic information of Signalling equipment shall be followed. Details of communication protocols and network media are given in following section.

6.5 Network and Communication protocols between subsystems

The exchange of information from IoT device to Local server and to Centralized Cloud shall be on standard format for interoperability between different systems.

The network architecture and communication protocols for Diagnostic data as defined in EULYNX standards shall be followed.

It is planned for adoption of standard protocols for all Signalling equipment in future. Hence, this system will be compatible for direct interfacing with the diagnostic ports of various equipment like Electronic Interlocking, Axle counters, etc.

As defined in EULYNX, the protocols SNMP v2c or OPC-UA shall be used to transfer diagnostic data from the connected systems (IoT) to the service function Diagnostics collector (Local server/Edge device).

The layers of network architecture as per EULYNX standard for the complete Diagnostic system is as shown in fig. below.

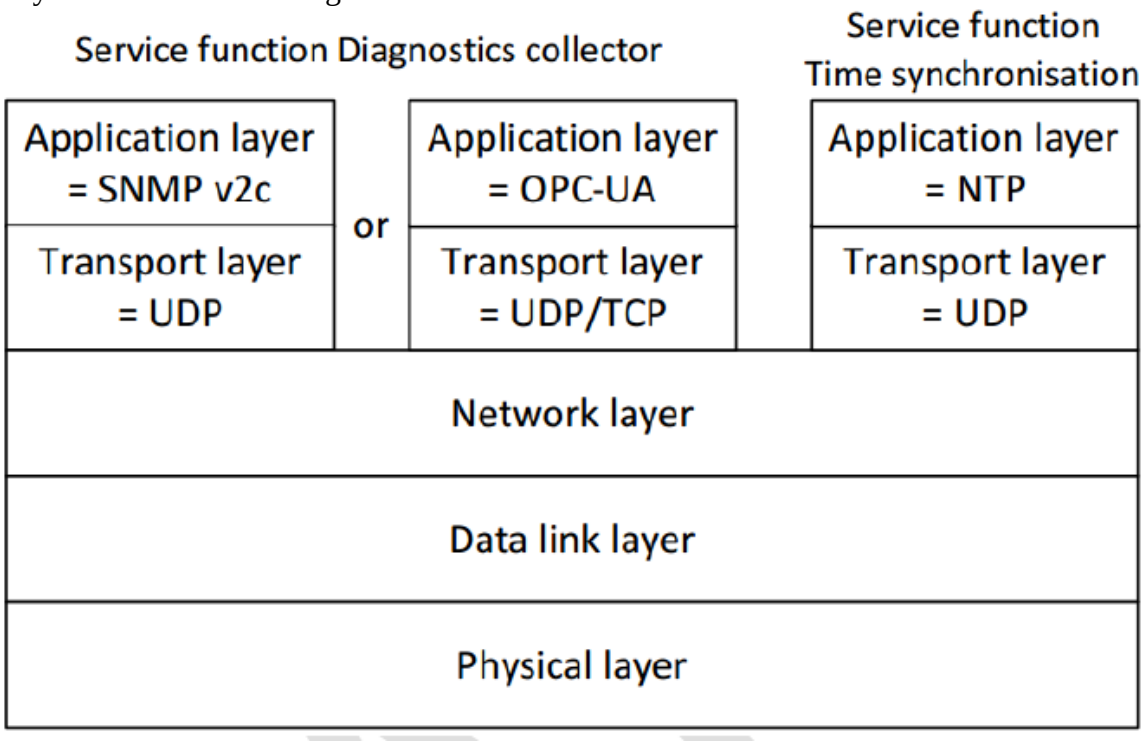


Figure 54: Network architecture as per EYLYNX standard

The following shall be the media between various devices.

- For communication from IoT device (in station yard near point, signals and other equipments) to Gateway at station –
  i) Wireless media on LoRA (or Zigbee or any open source technology) in free band of wireless spectrum.
  ii) Optical fiber LC interface [IEC 61754-20] (mandatory for outdoor field IoTs)
  iii) Copper cable. (RJ45 interfaces [IEC 60603-7])
- For communication from outdoor type IoT devices (for field gears like signal, point, track circuits, etc) to Gateway at station, the wireless connectivity is mandatory along with optional Fibre connectivity (Type LC connector).
- While for communication from indoor type IoT device (for IPS, Axle counter evaluator, Datalogger, etc) to Gateway at station – RJ45 (copper) and/or LC port (Fiber) shall be provided.
- For far away field IoT's like for IBH, if free spectrum wireless media is not feasible due to long distance, preferably OFC may be used.
- For communication from Station to Cloud, existing optical fibre network of Railtel shall be used.

6.6 Local Server and Edge computing

At each station there shall be centralized setup consisting of Gateway to collect the data from various IoT devices and a set of Local server with Edge computing. The basic architecture at station is depicted in *Figure 55*.

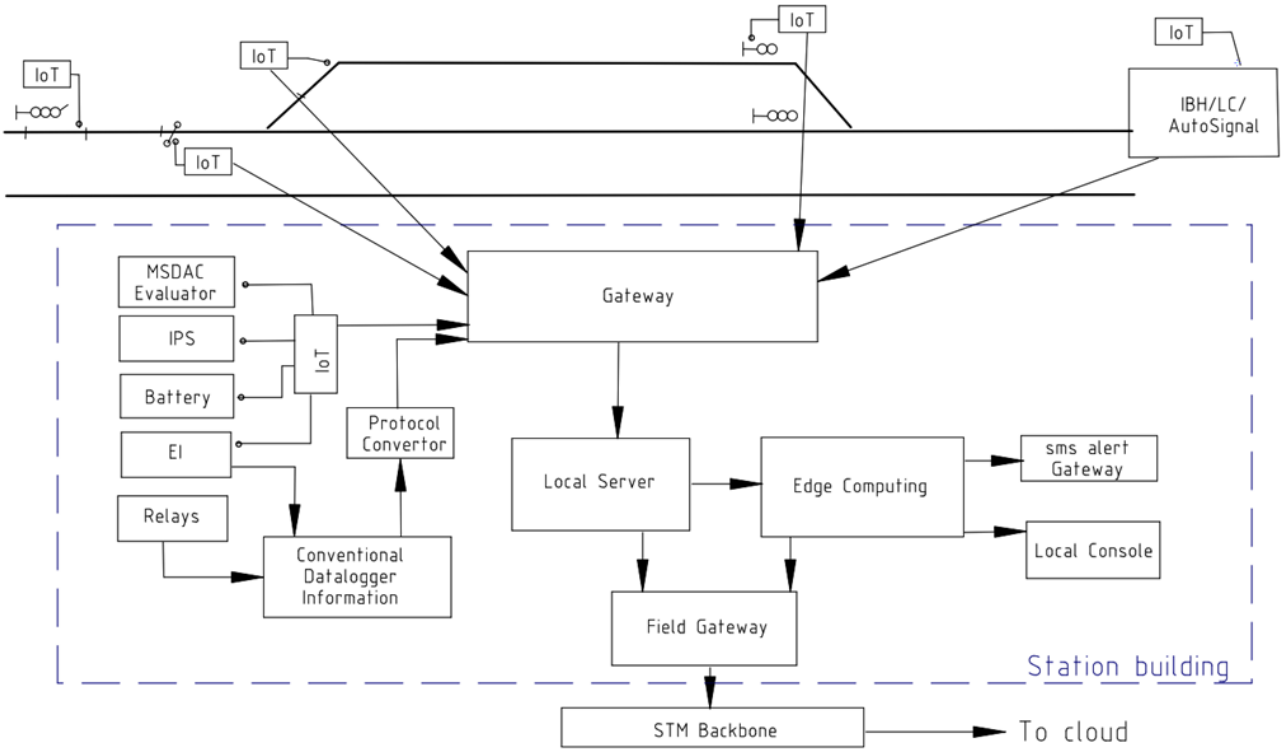


Figure 55: Arrangement at a station in RDPM

The following are the broad functions of Edge computing device:

Scrutinizing the local data of signalling gears to generate realtime alerts on the "deterministic failures".

For example – A Point has no indication of Normal or reverse for more than 10 second. The system will detect this as failure and using the data of voltage/relay monitoring at relay room, point motor, etc, it should generate an alarm that *"Point No. 101 of Station "ABC" has failed. Probable reason is – detection contact problem at A end"*

6.7 Field Gateway

At each station there shall be field Gateway which filters and pre-processes the data to be sent to and received from Cloud.

Field gateway will transmit/receive the data to cloud over the STM backbone of Railtel.

6.8 Power supply requirement at Station

The power supply for IoT devices near the outdoor equipments shall be taken from signalling equipment supply with suitable rating fuse. Where power is not existing, 24V DC may be extended from nearby location box.

The power supply for IoT devices in Indoor i.e. relay room shall be provided from 24V DC of IPS (preferably dedicated module in N+1 configuration).

The power supply for all other equipments i.e. Gateway, Local server, Edge computing device, etc shall be provided from 230V UPS of good quality. The input to UPS shall be from same source of IPS i.e. selective AT after auto-changeover of IPS.

6.9 Central cloud and Data Analytics

For all Zonal Railways, the platform for machine learning and Artificial Intelligence shall be common and open source.

For optimum outcome, it is proposed that there shall be integrated single cloud for all stations of Indian Railways

It is desirable that Cloud and AI shall be based on open source platforms.

Note: Developing AI algorithms and machine learning is a time taking job. The present Specification assumes one single platform to avoid wastage of time and efforts on developing AI machine learning algorithms.

The setup in the Centralized Cloud is depicted in *Figure 56*.

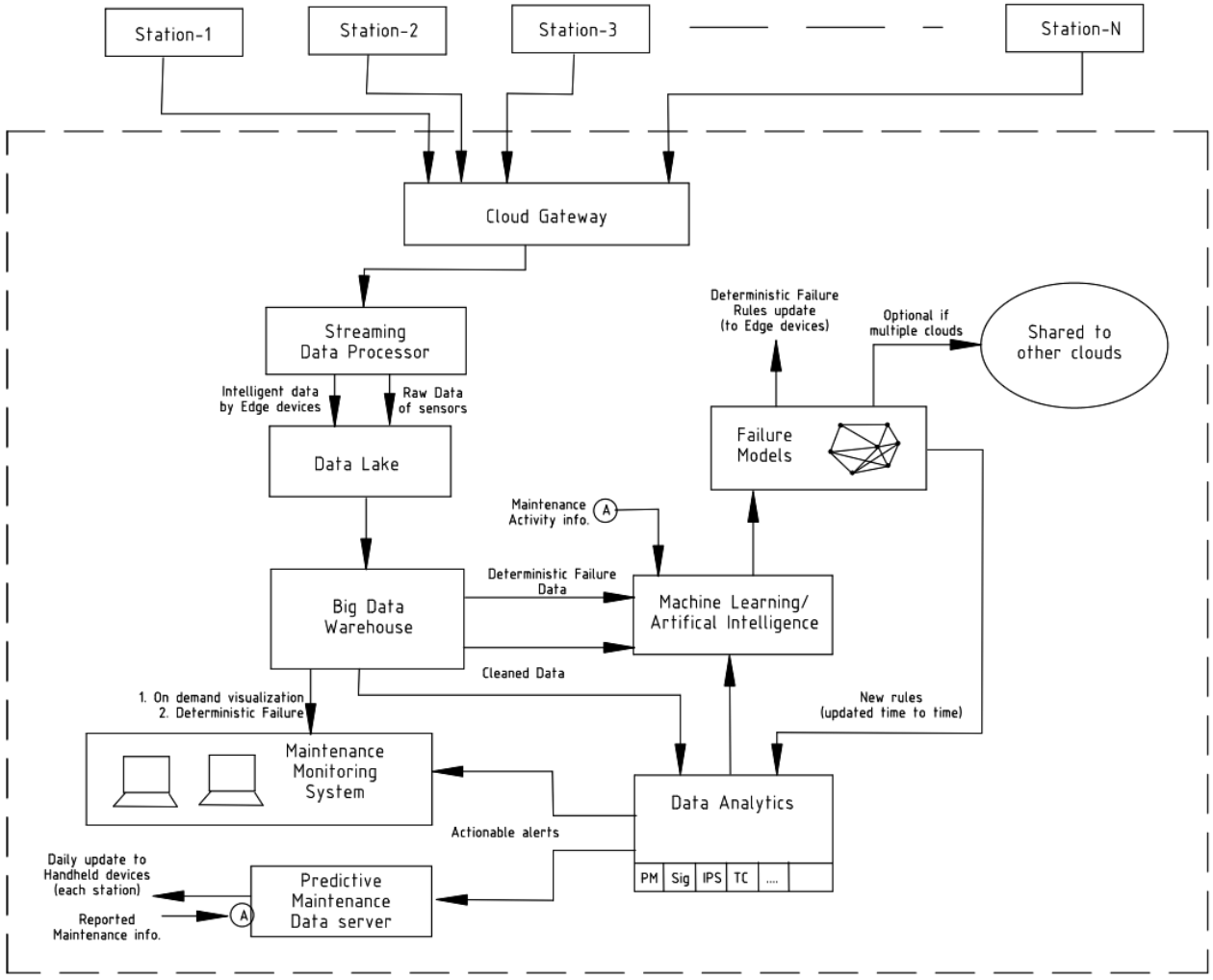


Figure 56: System Architecture at cloud level

(i) Cloud Gateway

It ensures safe data transmission and provides connectivity to various field gateways from each station.

(ii) Streaming Data processor

The sensor data received through cloud Gateway enters to streaming data processor.

(iii) Data Lake

A data lake stores the data gathered by sensors. It is still raw, so it may be inaccurate, erroneous or contain irrelevant items.

(iv) Big Data Warehouse

The big data warehouse stores cleansed structured data like:

- Various parameters of equipment measured at a particular time
- Equipment installation details (make, DOI, etc)
- Previous history of maintenance
- Failure
- Age
- Number of operations, etc

(v) Machine Learning / Artificial Intelligence

The data received is used by the AI algorithms to improve the failure models and predictive models. If deterministic failure is reported by Edge device, the machine learning will analyse deep data screening to relate failure pattern and update its model.

(vi) Data Analytics

The existing failure models and predictive models are updated time to time by the Machine learning above. The recognized data patterns are reflected to generate the predictive health information of signalling equipment.

(vii) Maintenance Monitoring System

It receives the predictive health information from the Data Analytics sub-system as well as has access to historical and live information of signalling gears from Big Data warehouse. It also consists of different terminals for monitoring the data by staff manned 24x7 for assisted maintenance and failure rectification. In addition, there shall be "Preventive maintenance Cloud" which relays the information to all handheld devices for updating the health information of each signalling gear on daily basis. Critical alerts will be sent on realtime basis assisted by automated alert system and manned supervision.

6.10 Methodology for Machine learning and AI techniques

During initial development of system, the supervised machine learning will be required and slowly it will switch to unsupervised machine learning using Artificial Intelligence (AI) techniques.

By monitoring patterns in real time and looking at historical data, the machine learning can identify repeat scenarios which it can then create rules for moving forward.

6.11 Alarms message and Maintenance Monitoring Terminals

The systems shall generate alarms in best possible manner such that the cause of failure is pin pointed so as to reduce the MTTR.

For example,
"Station ABC, Track circuit 2T failed due to high leakage current of "x" mA. Feed end current is "y" while relay end current is "z".–

Possible reason – Sleeper shorting – 80% (high probability because the drop is sudden), Low ballast resistance = 10% (low probability as leakage is not gradual), others – 10%."

The predictive alarms shall contain the detailed information with probability and end of usable life data. One example is as below for general guidance (but not limited to):
Message-Alarm example:

"Station ABC, Point 102A: Need lubrication and if it is not attended for lubrication, the probability of point failure is
5% in next 24 hours

20% in next 1 week

40% in next one month"

The terminals on maintenance monitoring systems shall display realtime alerts on the screen. Depending on the rate of failure data, suitable number of manned terminals for set of stations shall be provided.

The monitoring terminals shall provide alerts which shall be categorised as Minor, Major, Critical, etc.

The colour coding shall be done based on the severity of alert for quick attention.

The alerts information list should be concise. On clicking of the particular alert, the detail technical information of gear fault should come.

Based on the station, the contact information of on duty staff and higher escalation shall also be displayed for relaying the information by telephonic call to the staff concerned. As an example, the maintenance monitoring terminal is displayed above.

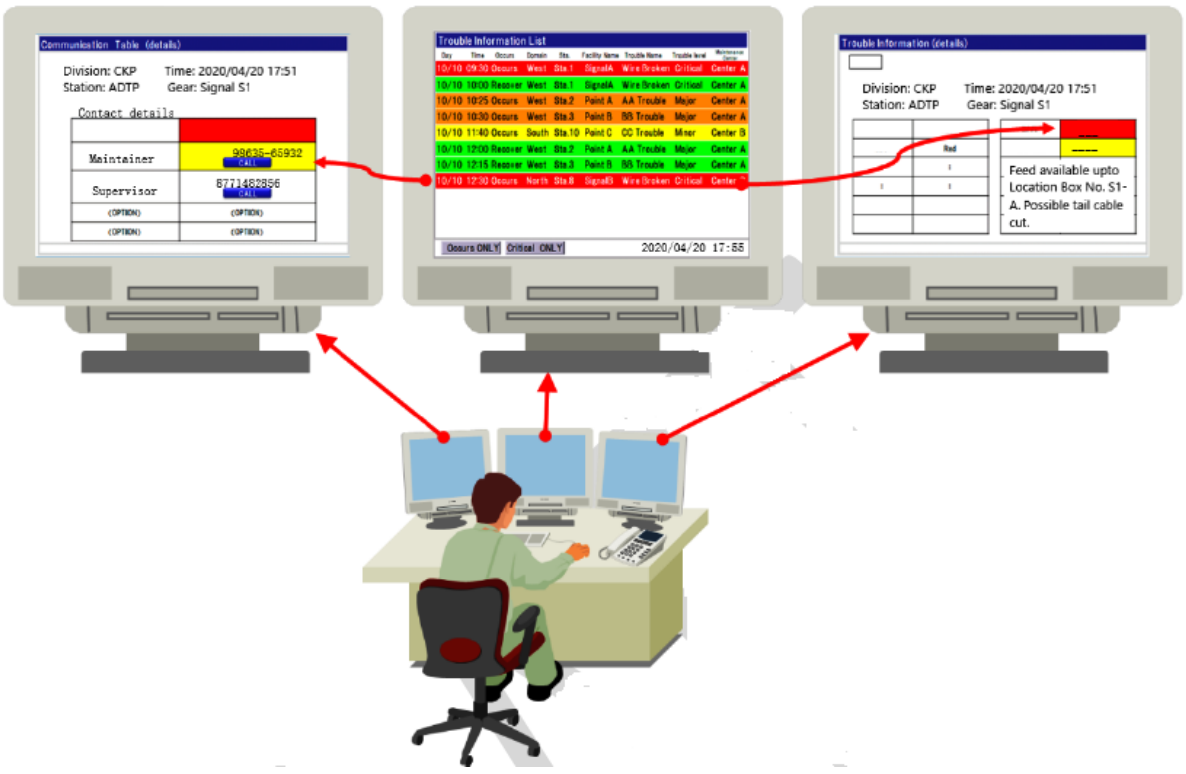


Figure 57: Maintenance Monitoring System

Based on the station, the contact information of on duty staff and higher escalation shall also be displayed for relaying the information by telephonic call to the staff concerned. As an example, the maintenance monitoring terminal is displayed above.

6.12 Parameters to monitor (Indicative)

The following are the parameters to monitor for Signal, Points and Track circuits in outdoor locations. This list is indicative and based on experience it may be improvised.

Table 7: Functions in outdoor locations in RDPM

Sr. No.	Functions	Status type
	Track Ciruit	
1	Feed end & relay end currents of DC track circuit	Value (Analog)
2	Track circuit feed voltage before feed resistance & choke	Value (Analog)
3	Status of local Track Relay (TR)	Status (Digital)
4	Track charger – Potential free contact	Status (Digital)
	Point Machine	
1	Point machine operating current	Value (Analog)
2	Point machine operating voltage	Value (Analog)
3	Point position (Normal/Reverse)	Value (Analog)
4	Vibration	Value (Analog)
	Signals	
1	Signal lamp Current Note: Individual lamp current for main aspect lamps and group of lamps in case of route & shunt.	Value (Analog)
2	Signal Lamp Voltage	Value (Analog)
3	Local Signal Control repeater relay's status at Location Box (Each aspect)	Status (Digital)
4	Illumination	Value (Analog)

Table 8: Details of Voltage and Current ranges of sensors for Point Machine, DC track Circuits and signal lamps

Signalling Gear	Voltage/ Current Range#	Minimum detectable change (2% of nominal value) (Indicative for initial tri-als)**
For Point Machine Operating current.	0-10 Amps DC	**
Point Machine Operating voltage	0- 170V DC	**
Signal lamp current	0-1 Amps AC	**
Track circuit current	0-3 Amps DC	**
Track circuit Feed end volt-age	0- 16V DC	**
Track circuit Relay end volt-age	0-10 V DC	**
Relay Operating voltage 24V Relays	0- 40V DC	**
Relay Operating voltage 50V Relays	0- 90V DC	**

Nominal values of operating parameters from respective RDSO Specification of equipment may be referred.

** As the Machine learning could be dependent on current and voltage signatures for different types of equipments, the minimum detectable change for each type of equipment will effect the end goal of predicting failures. Reducing minimum detectable change beyond a value would not be economical and may not be required for each and every gear. Hence, this requirement is indicative here and may require change after experience and trials.

6.13 Failure model examples (Informative)

The point's operating current signature (variation of current value with time during operation) can differentiate between various reasons of failures. For example, point failed due to stone obstruction between tongue rail and stock rail will have sudden rise of current after smooth displacement. While it will be different current signature for poor lubrication.

Similarly, based on particular point's historical data the system can know the displacement of tongue rail from average time taken for full displacement. The system can predict if the point has failed due to some obstruction (incomplete movement) by seeing the time length of normal current and point where current increase (obstruction). If current dropped at average time, then movement of tongle rail is full which shows that failure is possibly due to other cause like detection contact failure.

The health of cable core can be accessed by measuring the voltage at relay room and the voltage reaching the point machine. The drop of large voltage during particular point operation can be used to detect faulty cores in cable.

The DC track circuit failure identification in case of high leakage current can be predicted based on history of relay end current. If the leakage has in-creased gradually, it shows the poor ballast resistance due to rain or water-logging. While a sudden leakage current may show sleeper shorting.

The total number of operations of a relay may be used to assess its life. Au-tomated learning through AI techniques may find a trend in the life of relay in terms of number of operations and duration of cumulative pickup time of relays. Environmental parameters like temperature and humidity may have a relation to failures.

In case of cable cut, the disconnection is preceded by sudden break and make of cable continuity. The voltage/current monitoring signature of different cores of cable before discontinuity can be used to identify such incident. While sudden break of continuity may imply fuse blown.

Chapter VII
Real Time Monitoring System (RTMS)

7.1 Introduction

For predictive maintenance the health of the asset is monitored by measuring its health parameters. Before parameters reaching failure state, they are brought to normal value by attending the equipment. This is more scientific, it requires less efforts and improves availability of equipment. However in this approach condition monitoring/health of the equipment is required on a continuous real time basis. The Real Time Monitoring System (RTMS) works on the same principle.

7.2 Monitoring of field functions

RTMS monitors the following field functions by recording voltages and currents on real time basis as given below:

Track circuits
- Feed end: Charger Current, Feed end current, Choke Voltage
- Relay end: Relay end Voltage, Relay end current
- Relay room: TPR voltage
- Derivations: Leakage, Energization

Point Machine
- At location for Each End: Normal & Reverse Voltage, Current, Duration of operation
- Thrust & vibration at each end.

Signals,
- For Each signal Aspect: Voltage at location & current at relay room

Axle counter
- Supply voltage at location
- Channel Voltage at location

LC Gates
- Supply voltage of Motor
- Digital Input status of relay

Level of various DC and AC supply voltages.
- 24v supply voltage at each location
- 24v supply at relay room
- IPS battery Voltage
- AT supply AC voltage

Based on real time monitoring of asset, system shall be able to clearly identify change in values due to **train movement, on time failure, change in asset property.** Based on class of identification system shall **ignore, trigger, forecast failures** respectively.

7.3 General requirements of RTMS

- The **RTMS** shall be capable of **wireless networking of data logger** to control room & wireless networking of **UTS Think pad to UTS server**.

- The **RTMS** shall be capable of generating alarm under defined conditions in form of text message & alerts on cloud platform. In addition, RTMS shall have at least 5 digital output provision to drive any relay in order to achieve non vital operations like **healthy AT selection**, DG **operations**, charger **switching** etc.

- For **digital inputs, potential free contacts** shall be used. Analog signals shall be scaled to a suitable limit using signal conditioner before converting to digital signal.

- Any current Sensor to be used for RTMS shall be **non-inclusive clamp** type.

- **RTMS** shall be accessible remotely & shall prohibit a cloud platform to see data over cloud.

- Networking of RTMS with field unit shall be over wireless network **RF/Lora/WLan** based on physical condition of yard & Networking of RTMS with cloud shall be over **GSM** network.

- The system shall be easily re-configurable to any changes required by user, whenever modifications are carried out in the yard.

- RTMS shall be able to log collected per minute wise along with function for each gear to specify min, max, average, instantaneous value for the minute against each gear

7.4 Main Modules of the system

RTMS shall comprise of following components:

(1). RTMS (Real Time Monitoring System) Main unit.

(2). FTU (Field Transmission Unit).

(3). Wireless Network for yard: RF/LORA/WLAN

(4). Cloud Setup

Technical specifications

(1). RTMS (Real Time Monitoring System) Main unit.

RTMS main unit shall be in variant of 256/512/1024 data unit, to intercept various data units arising from different field gears spread over the yard. RTMS main unit shall have

- 50/100/150 analog channel,
- 5/10/15 digital input/output
- 1/2/3 one wire port for temperature sensor

in respective version of 256/512/1024 data units' variant.

Any analog module to be used in RTMS shall be of generic in nature and shall follow standard Modbus RS 485 protocol so that can be easily integrated with any system.

For Cloud networking, RTMS main unit shall have provision for USB DONGLE, as well as ETHERNET port option to increase redundancy.

In order to have wide interfacing, RTMS main unit shall have provision of

- RS 232
- RS 485
- TCP/IP

to connect with any IOT module/sensors.

RTMS main unit shall have provision for wireless networking of Datalogger & UTS system with control.
RTMS main unit shall be powered over a wide voltage range of 0-220v AC/DC**.**
Power Consumption max 10 watts.
RTMS main unit shall posses its unique Mac id for differentiating from other RTMS units.
RTMS main unit shall have Web Server Interface to allow remote access for

- Updating firmware
- Operating System
- Data log &export configuration, also provision to export data to any desired IP.
- Configuring polling interval, Calibrations of FTU channels
- Configuring wireless channel for each FTU from either RF/LORA/WLAN
- FTU configuration, should be generic in type to support any MODBUS RS 485 devices.

16GB Micro SD card to store local data in case Cloud Connectivity goes out.
RTMS main unit shall have provision to connect with FTU over RF/LORA & WLAN simultaneously to ensure dual network for communication.
RTMS main unit shall be able to communicate with other RTMS main unit in order to integrate monitoring for hut -power cabin setup where distance between power cabin & hut can be comparatively large.

(2). FTU (Field Transmission Unit).

Base Version of FTU shall be at least of 20 channels. Scalable in multiples of 10 channel up to 50 channels.
Each FTU shall have dual mode of connectivity RF/LORA & WLAN.
Each channel shall be configured as per choice as either analog input or digital input.
Each Analog channels shall be configured as per choice either for voltage or current
Power Supply :110v AC.
Power Consumption :5watt max.

(3). Wireless Network for yard: RF/LORA/WLAN

Each Yard Shall be covered over LORA/RF +WLAN network to ensure dual communication between RTMS & FTU.
RTMS shall be able to switch between RF /LORA & WLAN as and when require
LORA/RF shall be max 1watt rating and should be in free band zone in INDIA.

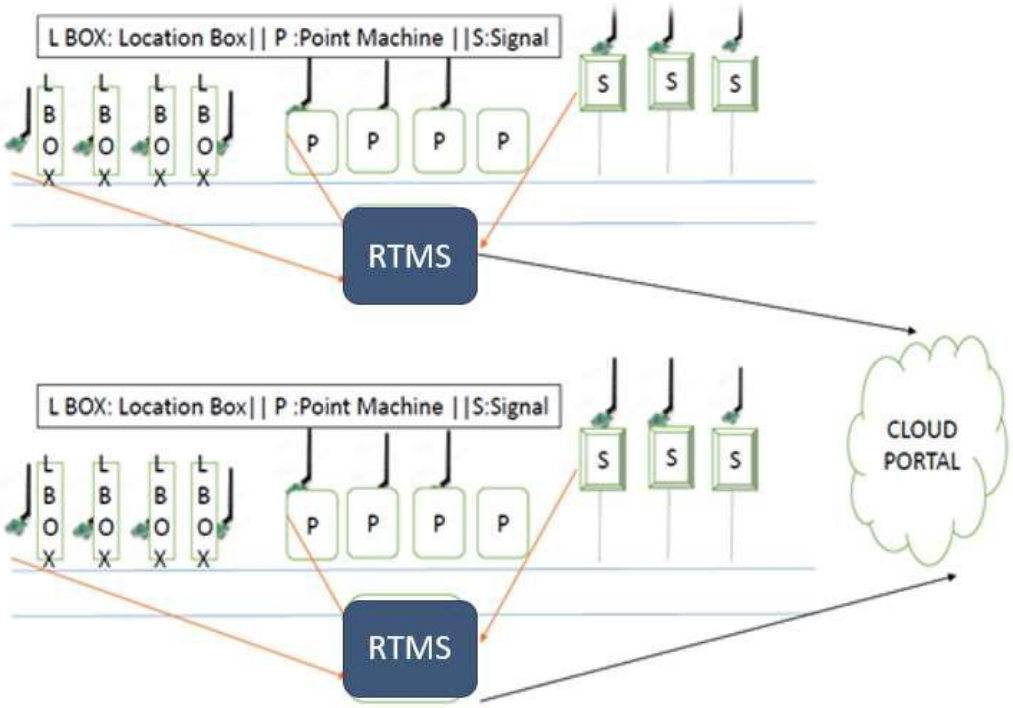


Figure 58: RTMS System Architecture

(4). Cloud Setup

(i) Main dash board

There shall be a main dash board for each division. Once logged in landing page should be main dash board with following provisions:

General overview for all sites: There shall be a master overview on dash Board, which shall populate list of all RTMS unit installed at stations along with current status of the device as Active or last active

Reporting:

Reporting page from where you can choose to download specific logged data for any site in a CSV format.

Alerts page, where you can monitor any alarms or event notifications shared by the RTMS on each site.

(ii) Individual Dash Board

On main dash board, each row entry of RTMS shall have option to link to real time dash board of that RTMS unit. Real time dash board shall have following provision for respective field function.

Landing Page shall be any one filed function & option to navigate to other field function & graphs.

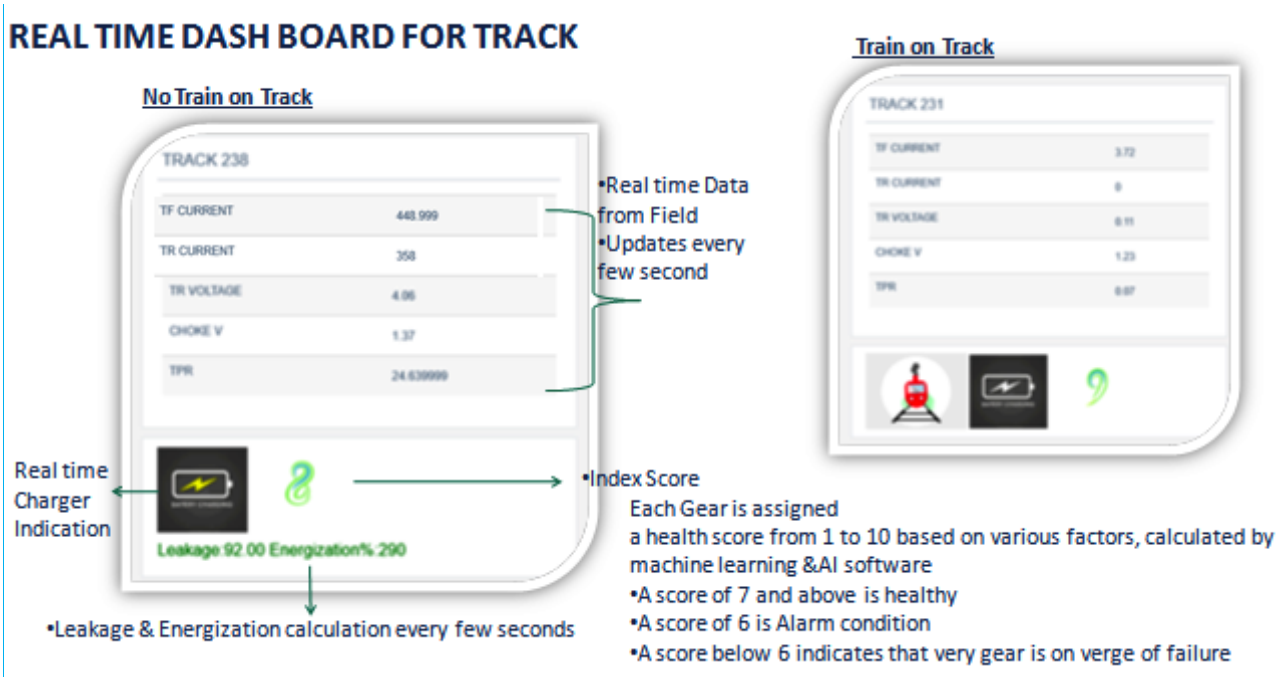


Figure 59: RTMS Real Time Dash Board for Track Circuit (Courtesy : M/s Energy7)



Voltage & Current in Real time of active Signal Aspect
Figure 60: RTMS Real Time Dash Board for Signal (Courtesy: M/s Energy7)

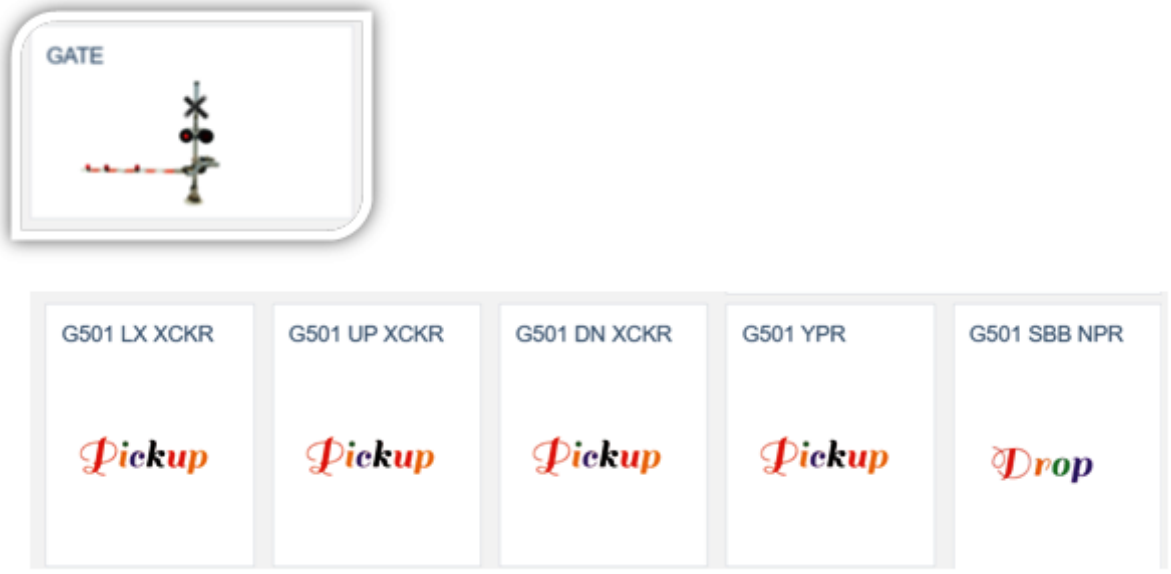


Figure 61: RTMS Real Time Dash Board for LC Gate (Courtesy: M/s Energy7)

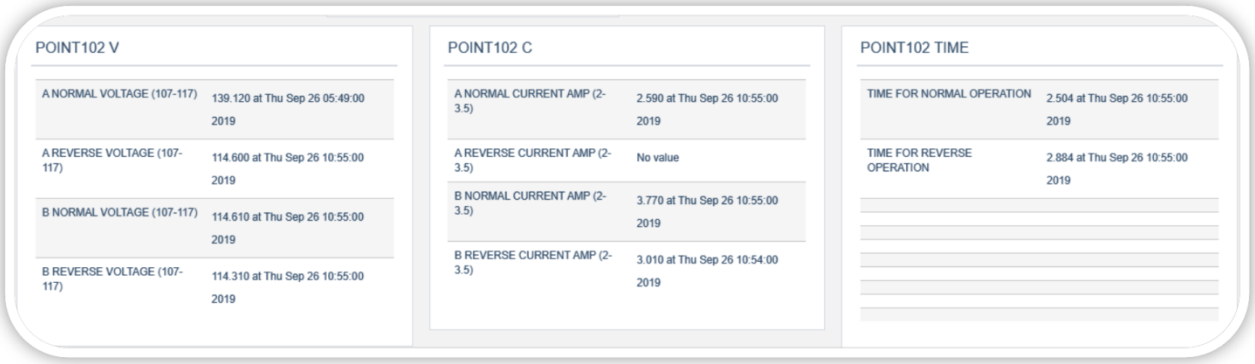


Figure 62: RTMS Real Time Dash Board for Point Machine (Coutesy: M/s Energy7)



Figure 63: RTMS Real Time Dash Board for Point Machine (Courtesy: M/s Energy7)

(iii) Current Interface

No existing circuit shall be interrupted to ensure safety. Any current shall be measured via clamping sensors, which in turn is connected to IoT device.

Current sensors to be used should be of type output as voltage for general Integration with any systems.

Type of current sensor for different field function can be found below.

Table 9: Current sensors for field functions

Track Circuit	0-700 ma DC for TF & TR A, min resolution 5 ma
	0-10 A DC for track Feed Charger, in resolution 50 ma
Point Machine	0-10 A for track Feed Charger, in resolution 50 ma
Signal	0-400 ma AC, min resolution 5 ma

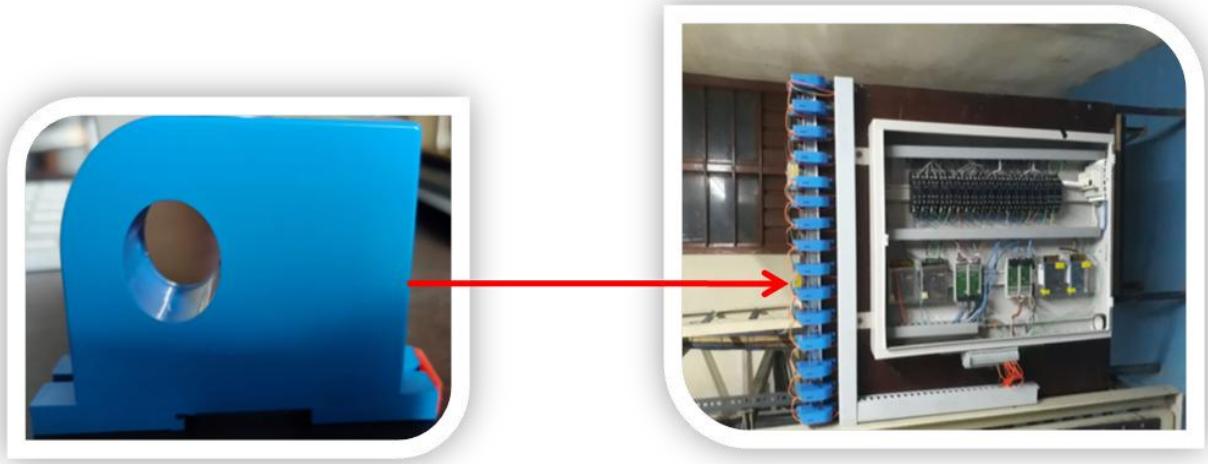


Figure 64: Current Sensor Rack & Main Server at Relay Room of RTMS (Courtesy:M/s Energy7)

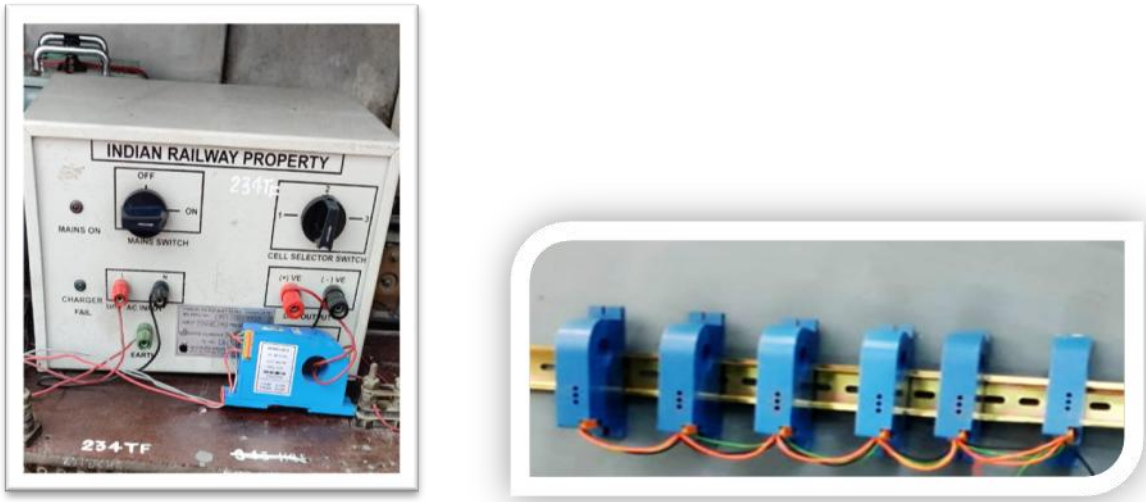


Figure 65: Current Sensor for Charger indication & Leakage current in Field Transmission Unit of RTMS (Courtesy: M/s Energy7)

(iv) Voltage Interface

Any DC Voltage shall be interfaced in tune to following:

Any AC voltage shall be interfaced with Galvanic isolation

DC isolation circuit shall have following characteristic

- Input
  - 0-50v for Track
  - 0-150v for Point machine
- Power :12 V
- Output :0-5 V DC

7.5 Functional requirement specification

(1). Data Logging
(2). Data Streaming
(3). Alerts

- Failures
- Thresholds
- Change in property

(1). Data Logging

Data shall be logged per minute basis with following function

Table 10: Criteria for data logging in RTMS

TRACK	TF A	MAX VAL OF MINUTE
	TR A	MIN VAL OF MINUTE
	TR V	VAL OF MINUTE
	CHOKE V	MAX VAL OF MINUTE
	CHARGER A	AVERAGE VAL OF MINUTE
	TPR	MIN VAL OF MINUTE
SIGNAL	ASPECT VOLTAGE	MAX VAL OF MINUTE
	ASPECT CURRENT	MAX VAL OF MINUTE
POINT MACHINE	NORMAL & REVESE VOLTAGE	MAX VAL OF LAST OPERATED WITH TIME STAMP
	NORMAL & REVESE CURRENT	MAX VAL OF LAST OPERATED WITH TIME STAMP
	TIME OF OPERATION	MAX VAL OF LAST OPERATED WITH TIME STAMP
24V AT LOCATIONS	VOLTAGE	MAX VAL OF MINUTE

(2). Data Streaming

All yard data shall stay on standby, only once dash board is open RTMS shall start streaming data to dash board on clock of few seconds data stream update time shall not be more than 15 seconds for field function Track, Signal, 24v.For Point Machine format shall be last operated.

Graph of each field function shall appear together. For example, a track graph shall contain all its parameter in single graph with function to enable /disable parameter in that graph window such that user can view all parameters at a time or by enabling or disabling parameter graph should change accordingly. Graph shall have option of month to select time range like yesterday, past 7 days, past one month or any custom date range. Also graph shall have option for CSV download & image download

(3). Alerts

- Failures
- Thresholds
- Change in property

(a) Failures

Table 11: Failure logics

TRACK	RTMS shall automatically understand events of train movement, if there is no train & TRACK fails, system shall generate track failure message (sms & cloud). Message shall also contain all gear parameters of that very track.
SIGNAL	SIGNAL BLANK
POINT MACHINE	OBSTRUCTION alerts based on time of operation. If found true shall generate alert along with operated mode (Normal /Reverse) Voltage, Current, Time of Operation
24 V	On Zero.

(b) Threshold

Table 12: Threshold values

TRACK	TR V	2.5-4.2 V
	CHOKE V	0.6-1.8
	CHARGER A	<500 MA
	TPR	< 20V
SIGNAL	VOLTAGE	<100 V
	CURRENT	<110 MA
POINT MACHINE	VOLTAGE	<100 V
	CURRENT	<1.5 & > 3
	TIME OF OPERATION	>3 SEC
24 V	VOLTAGE	<22 V

(c) Change in property

RTMS shall identify any deterioration in property of field function using recorded data and forecast future failure.

■■■

Annexure – Railway board letter on Predictive Maintenance policy.

GOVERNMENT OF INDIA/ भारत सरकार
MINISTRY OF RAILWAYS/ रेल मंत्रालय
(RAILWAY BOARD)

No. 2020/E&R/7(13)/4 New Delhi, dated 10.07.2020

The General Managers, All Indian Railways/PUs, NF/Con., CORE
DG/RDSO/Lucknow, DG/NAIR/Vadodara
CAOs, DMW/Patiala, WPO/Patna, COFMOW/NDLS, RWP/Bela, CAO/IROAF

Sub: Predictive System with data acquisition, diagnostics and remote monitoring facility for all assets on Indian Railways

In order to move from Schedule based Maintenance regime to Predictive based Maintenance regime and from Codal life based asset replacement to Condition based asset replacement, full Board have approved the following:

1. All systems/equipment being introduced on IR should have a data acquisition system, diagnostic and remote monitoring sub-system(s) to move towards a predictive maintenance regime.
2. RDSO/PUs, as per the control of the items, should develop specifications/functional requirements and systems regarding data acquisition system, diagnostic system and remote monitoring sub systems for all existing equipment/systems as part of the overall system. Also, the same should be incorporated during approval of the new products in future to optimize the Total Cost of Operation (TCO).
3. To integrate with domain specific (Civil, Loco & Traction, Rolling Stock, Signalling & Telecom, etc) predictive systems, data from subsystems may be shared in a secured manner including through Application Programming Interface (APIs). While approving a system/subsystem, it should be incorporated to share Data/APIs for the purpose and for integration with domain specific predictive systems.
4. The system will be integrated with existing or upcoming asset management systems such as Track Management Systems, etc.
5. Thereafter, the Common Asset Management Dashboard will be prepared. RDSO to integrate and deploy the prototype of the same.
6. The Diagnostics & Remote Monitoring sub-System may preferably be based on open standards.
7. Railway OFC will be the preferred backbone for data transmission or connecting to IoT devices across its routes. Once the LTE will be operative, the same will also be part of backbone data transmission.

8. The predictive data regime shall utilize the RailNet system to the extent possible as network infrastructure to optimize the cost of networking.
9. The data may be kept on the Cloud/Central Servers as per the Govt policies regarding data storage, for security of the data. This will give advantage in terms of reduced hardware and enhanced outcome. The deployment of cloud is a skilled job but optimizes the cost.
10. A Pilot project may be initiated for application-specific integration of all the existing predictive tools, currently in use on IR for monitoring of specific type of assets and development of predictive maintenance dashboards for Track, Rolling Stock, Signalling Systems, Bridges etc. for a focused and effective implementation. RDSO may propose such works, if required. Also, a common Asset Management Dashboard to be prepared with this.
11. DG/RDSO shall form a multi-disciplinary team of Executive Directors (EDs) and develop an integrated approach to asset maintenance where synergies bring value. The regimen should encompass all infrastructure assets and rolling stock in an integrated way to anticipate and pre-warn on maintenance requirements and prevent any failures.
12. RDSO may furnish the progress to the Board's office monthly through MCDO to CRB.

Kindly acknowledge the receipt and ensure compliance.

10.7.2020

(Umesh Balonda)
Executive Director (E&R)
Railway Board
E-mail: eder@rb.railnet.gov.in

Copy: As per list attached.

Contd.....

No. 2020/E&R/7(13)/4 New Delhi, dated 10.07.2020

Copy to:

The ADAI (Railways), New Delhi
The Director of Audit, All Indian Railways
The Director, Indian Railway Institute of Civil Engineering, Pune.
The Director, Indian Railway Institute of Mechanical and Electrical Engineering, Jamalpur.
The Director, Indian Railway Institute of Signal Engineering and Telecommunications, Secunderabad.
The Director, Indian Railway Institute of Electrical Engineering, Nasik.
The Executive Director, Indian Railways Centre for Advanced Maintenance Technology, Gwalior.
The Director, Indian Railway Institute of Transport Management, Lucknow.
The Registrar, Railway Claims Tribunal, Delhi.
The General Secretary, IRCA, New Delhi.
The Chief Commissioner of Railway Safety, Lucknow.
The Secretary, Railway Rates Tribunal, Chennai.
Managing Director, CRIS, Chanakyapuri, New Delhi

Copy to:

The Genl. Secy., AIRF, Room No. 248, & NFIR Room No. 256-C, Rail Bhavan
The Secy. Genl., IRPOF, Room No. 268, FROA, Room No. 256-D & AIRPFA, Room No. 256-D Rail Bhavan

Copy to:

PS to MR, MOS(R)
CRB, FC, ME, MTR, MRS, MT, MST, MMM, SECY, DG (RHS), DG (RPF), DG/HR

10.7.2020

(Umesh Balonda)
Executive Director/E&R
Railway Board

References

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2. AVPL Technical notes on ELD type 905-B4
3. M/s Energy7 PPT slides on Condition monitoring of Signalling Assets.
4. Draft RDSO Specification for RDPM
5. RDSO Guidelines for Data Logger system
6. IRS Specification No.S99-2006 for Data Logger system
7. RDSO Specification no. RDSO/SPN/256-2002 for ELD.
8. Policy draft for Real Time Monitoring System (RTMS)
9. Policy Letter dated 10.07.2020- Predictive System on IR.
10. M/s Efftronics Ltd Presentation slides.
11. Centre MTC User Manual –M/s Kyosan
12. Station MTC User Manual –M/s Kyosan
13. Kyosan Centralized Management Systems
14. Literature on Networking of Maintenance Terminal

Quality Policy

“We at RDSO Lucknow are committed to maintain and update transparent standards of services to develop safe, modern and cost effective railway technology complying with statutory and regulatory requirements, through excellence in research, designs and standards by setting quality objectives, commitment to satisfy applicable requirements and continual improvements of the quality management system to cater to growing needs, demand and expectations of passenger and freight traffic on the railways through periodic review of quality management systems to achieve continual improvement and customer appreciation. It is communicated and applied within the organization and making it available to all the relevant interested parties.”



INDIAN RAILWAYS
Centre for Advanced Maintenance Technology
Maharajpur, Gwalior (M.P.) Pin Code – 474 005