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Remote Diagnostic and Predictive Maintenance System

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Abstract:- Nowadays, the railway industry is in a position where it can seize the opportunity of the Internet of Things (IoT) based predictive maintenance on the most frequently used active gears. The most important department in the Indian railway is Signaling Department. Track Circuit, Point Machine, and Signals are the critical systems in the operation of Railway. The traditional approach of periodic maintenance can be replaced by condition based predictive maintenance system which gives advance warning of potential failures, Predictive analysis based on Artificial Intelligence and Deep Learning technique leads to reduction in disconnection memo, Mean Time to Maintenance, cost of operation & maintenance.

Keywords:- *IoT, Predictive, Event Logger, Track Circuit, Point Machine, Signals, Machine Learning, Artificial Intelligence*

I. INTRODUCTION

Indian Railways (IR) is a governmental body under the Ministry of Railways which manages India's national railway system. It is run by the government as a public benefit and manages the third-largest railway network in the world by size, with a route length of 68,155 km (42,350 mi) as of March 2019.[3] Railway signaling is a system used to direct railway traffic and keep trains always clear of each other. The heart of Railway signaling systems are Point Machine, Track Circuits and Signals. To keep the whole system up it is particularly important to maintain these gears and prevent from failures or accidents. Condition Monitoring and Predictive analysis can be helpful to prevent from failures before they happen.

Predictive analysis and condition monitoring can be achieved using cutting-edge technology like Machine Learning, Artificial Intelligence, IoT, etc. But in this all technology requires a data as primary requirement. By Measuring the voltage and current parameters continuously with the help of data acquisition unit called Event Logger. Also, it is important to measure the data non intrusively to ensure the safety of existing railway circuits.

Point Machine

Point Machine is a device which is used for the operating railway turnout especially at a distance. An electric motor and gears to convert the rotational motion of the motor into linear motion.

Fig.1

Working of Point Machine:

Point Operation is done with Electrical DC Motor or Manually by Mechanical lever connected to shaft. Point is operated by a two position switch or two buttons from panel or with a lever from cabin by station master (SM). Since the relays are in interlocking state, they will be operated with the operation of single knob. Point normal and reverse indications are given to Station Master by LEDs.

To Monitor the Point Machine following parameters need to be measure:

- Operating Voltage
- Peak Voltage
- Peak Current
- Operating Current
- Obstruction Voltage
- Obstruction Current
- Operating Time
- Obstruction Time

DC Track Circuit:

DC Track circuit are used to determine the status of rail track i.e Occupied/Unoccupied. In each track circuits, there are multiple sections and each section having length of max 450m.At feed end voltage is given and at relay end receives the voltage when train comes because of short of circuit in relay end voltage becomes zero and track relay changes its status to Drop.

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Working of DC Track Circuit:

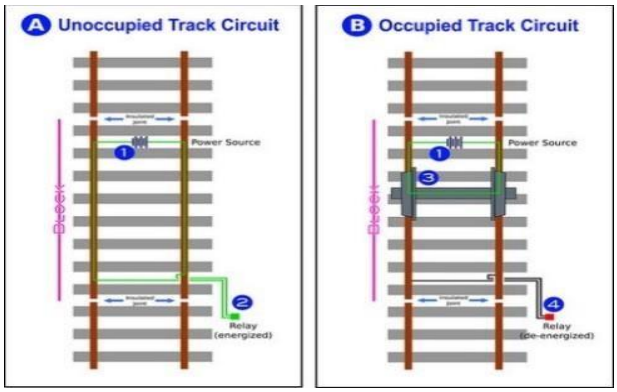

Fig.2

In the above fig shows the unoccupied and occupied condition of DC track circuit. Where station master can know the status and direction of the track.

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In DC Track Circuit, following are the important parameters to be monitored:

- Feed Voltage & Current at Feed End
- Relay Voltage & Current at Relay End
- TPR at Relay End
- Choke voltage
- Charger output voltage & Current
- Charger Input Voltage

Signals

A railway signal is a visual display device that conveys instructions or provides advance warning of instructions regarding the driver's authority to proceed.[3] The driver interprets the signal's indication and acts accordingly. Typically, a signal might inform the driver of the speed at which the train may safely proceed, or it may instruct the driver to stop.

Fig.3

In Signal, following are the important parameters to be monitored:

- Each aspect Voltage and Current
- TPR Relay Voltage

II. PROBLEM STATEMENT

A. Point Machine

The Point Machine operates when there is any diversion of train from one track to another track. Usually point machines are far away from the station and when point is operated there can be obstruction in between stock and tongue rail results train delay. Sometimes obstruction in between the rails but the point is set and lock that can affect next operation of Point Machine.

Due to many numbers of active components in point motor the chances of failures increase. Due to poor lubrication the point machine can draw more current than its normal operating current. Due to improper high or low pressure on lock nut rods can create unsafe condition to the point.

B. DC Track Circuit

The DC Track circuits operates with the help of Feed voltage from Battery and the battery needs to charge continuously with the track feed battery charger then receives at the relay end away from feed end this leads generation of leakages, ballast resistance and track resistance. So, it is required to maintain these parameters not exceeding to its permissible range.

Most of the time Charger gets fails or turned off and battery does not charge properly cause failure of sufficient delivery of feed voltage. Choke filters the noises in the voltages sometimes coil failure of choke can leads to generate spikes in the voltage.

When Train Enters into the section and exits from the section, Track circuit should clear, and unoccupied but sometimes specific Track Circuit gets not clear and shows occupied.

Track circuits gets fails due to 24 V External DC Supply or relay fails, sudden break of jumper cable or fuse blown off.

C. Signals

In Signals most of the failures happens because of fuse blown off, quad cable leakage, load current on aspects decreases gradually and reach to its permissible range. Wrong operation of signals. Signal bobbing.

III. PROPOSED SOLUTION

The Event Logger RTU which is a microprocessor based data acquisition unit continuously monitors the voltages and current at the outdoor cable termination point and sends the data to cloud/server with the help of available communication media like Zigbee/LoRA/LTE/Ethernet.

On the server/cloud with the help of IoT and AI-ML Platform we can get the real time analytics on the data. With the help of timeseries data & various machine learning algorithm like linear regression, ARIMA models can be helpful to predict the future failures of the gears.

A. Solution Architecture

In below architecture shows the solution architecture how the signaling gears can be monitored using the Data acquisition system, sensors and IoT systems. The RTU device collects the data and send the data directly to the cloud with the help of IoT protocol MQTT which is widely accepted worldwide. In server/cloud data streams, process and generates reports and alerts which can be access via web and mobile app in real time basis.

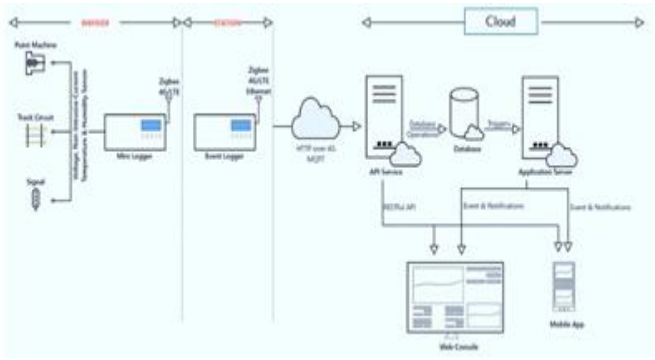


Fig.4 Solution Architecture

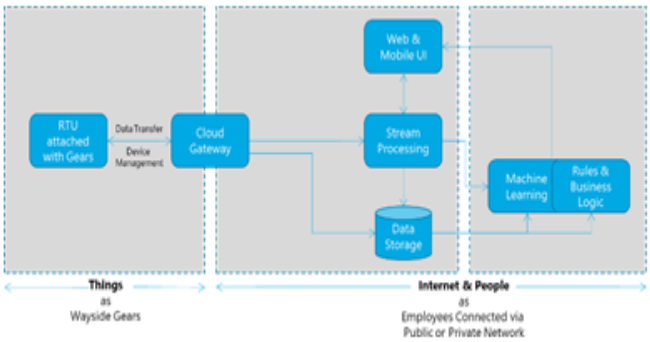


Fig.5 IoT Architecture

B. Measurements

- Galvanic isolation for all voltage and digital input points. AC Voltage measurement follows the concept of true rms for the better accuracy. DC measurement can be done with less than 10ms scanning rate for instantaneous spikes.
- All current measurement is non-intrusive with the help of open loop hall effect current transducers with highest accuracy.
- Point Machine Current signature measurement sampling rate is 10msec.
- Peak current measurement with the help of lowest scanning rate and high response rate sensors.
- Track Circuit current measurement is in milli amperes for better accuracy.

C. Communicaation/Data transfer

The communication media can be use as per availability and the requirement. Data transfer from the RTU device to the server/cloud can be possible with the following methods of communication:

1. LTE/4G/NB-IoT
2. LoRA/WIFI/Zigbee Local Network
3. OFC
4. Ethernet
5. Quad Cable

D. Data Storage & Analytics

- The data is stored at centralised database.
- The data is stored at the local RTU devices if there any network failure happens. Data logging at the device level.
- Application for data processing and data analytics on real time basis.
- Micro services which can be integrated with the data for Machine learning algorithm.
- Timeseries data can be useful for the analysis of prediction of future data.
- Warnings sends to the respective persons before potential failures happens.
- Powerful rule engine which helps user to configured threshold on various parameters and get alerts.
- Various graphs and charts for visual analytics.

IV. RESULTS AND DISCUSSION

The results are based on the working system being used by the North Central Railway. The observation for the point machines, track circuits and signals are available. The trials is in progress to make overall system effective for maintenance of S&T gears.

Point Machine

In below graph shows the point obstruction, abnormal and normal operation where the normal operation ends in 2-3 sec and abnormal events take more time and current to complete the operation and there is point where point is taking max current and time > 6 sec is obstructed with something in between sleepers.

The below graph shows when the point machine starts its operation currents goes to peak and after 1 sec it gradually decreases and continues till its steady operation ends, before set and lock again the current increases and goes down to zero.

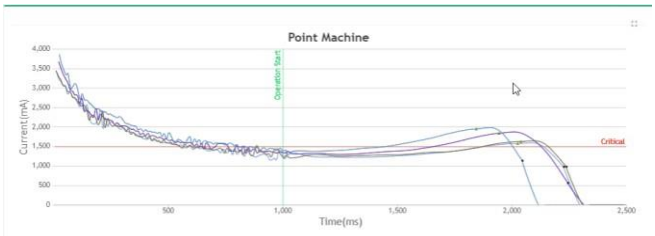


Fig.6 Normal Operation

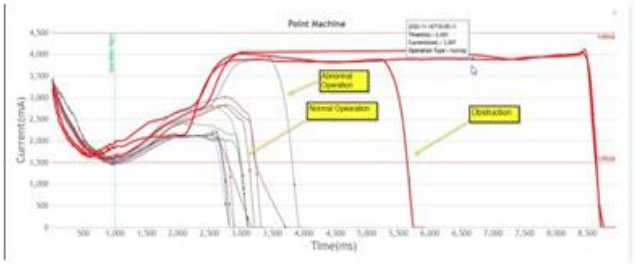


Fig.7 Obstruction, Abnormal, Normal operation

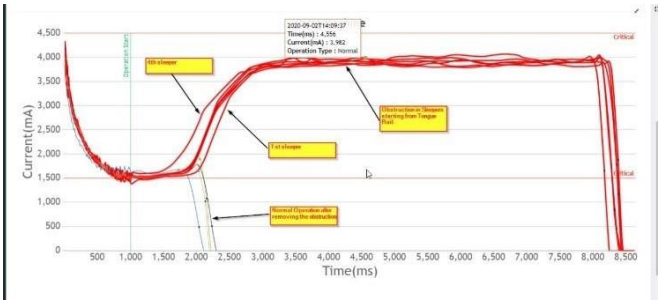


Fig.8 Obstruction in Different sleepers

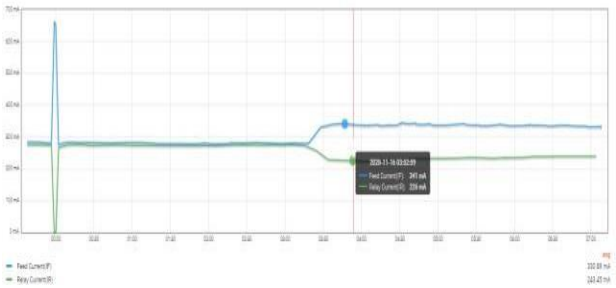
Fig.9 Utilization Reports of Point

DC Track Circuits

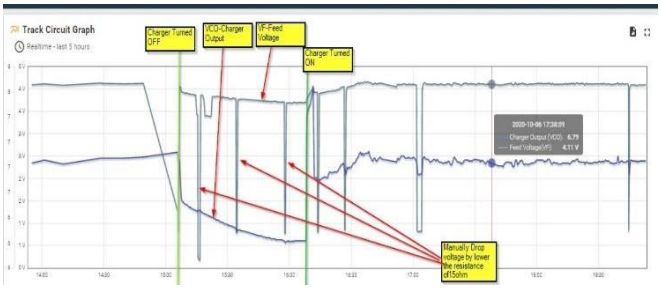
In DC Track Circuits observed that the leakage increases gradually when there is rain on the track which leads decrease in voltage at feed and relay and TC gets failed. Giving advance warning of increased leakage helps the maintainer to maintain the track circuit properly.(Refer Fig.10)

Due to periodic maintenance or track feed charger fail charger often stop charging the battery and the track feedruns on battery and after the certain period it gets failed due to non-charging. This can be eliminated by giving the prediction before the track fails when charger stops giving output.(Refer Fig 11)

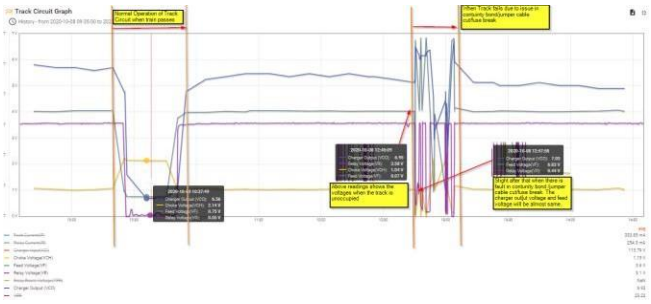
Failure of Track circuit when there is cut on the jumper cable/continuity bond having the graph which gives the exact root cause of the failure. This helps maintainer to find out the root cause of failure.(Refer Fig 12)



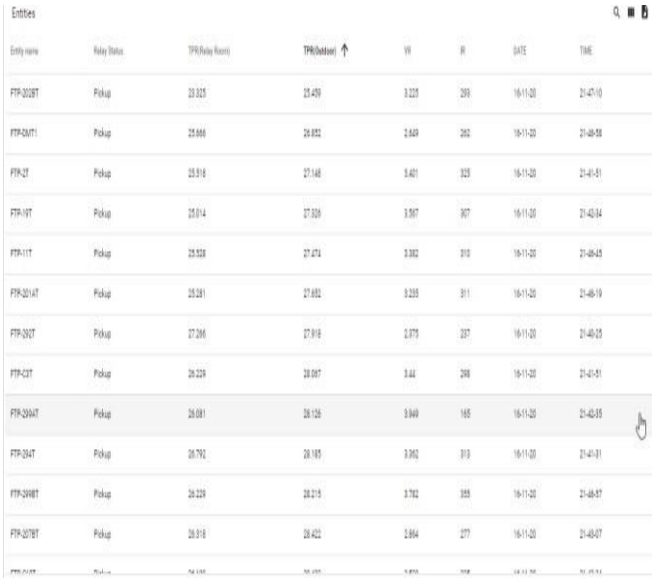
(Fig.10) Increased Leakage



(Fig.11) TC going to fail due to charger fail



(Fig.12) TC Failure due to continuity bond cut



(Fig.13) Relay Room Status

Alerts and Alarms

Created Time	Gear Name	Gear Type	Alarm Type	Severity	Status	Event Count	Ack Time	Cleared Time
2020-11-16 15:08:26	FTP-201A	PM	PMObstruction	CRITICAL	CLEARED_UNACK	0		2020-11-16 15:08:38

Parameter	Value
ALERT_DESC:	Obstruction in Point Sleeper Detected
ALERT_VALUE:	8648
ALERT_TYPE:	Point Machine Obstruction
DEFAULT_RANGE:	15ec to 65ec
DYNAMIC_RANGE:	1.55ec to 5.55ec
EVENT_COUNT:	0
ACK_BY:	
CLEARED_BY:	
CATEGORY:	
COMMENT:	
ACTION_TAKEN:	
OC:	3679
ATTACHEMENTS:	

V. ROADMAP AND FUTURE CHALLENGES

1. Trials on multiple station and multiple gears shall be equipped with Remote diagnostic and predictive maintenance system to get the maximum dataset to train and optimize machine learning algorithms.
2. Scheme for calibration of sensors.
3. Interoperability with multiple vendors.

VI. CONCLUSION

The condition monitoring and predictive maintenance system for railway signaling gears helpful for railway to reduce the MTTR and MTBF. The prediction or forecasting of failures can be useful to achieve the zero failures goals.

24x7 online monitoring of the gears will reduce the periodic maintenance activity and reduction in manpower.

ACKNOWLEDGMENT

The first author would like to thank North Central Railway for the contribution on globally rising technology IoT and AI-ML for the Indian railway.

ABBREVIATIONS
AI – Artificial Intelligence ML- Machine Learning RTU- Remote Terminal Unit IoT – Internet of Things
MQTT- Message Queuing Telemetry Transport LTE – Long Term Evolution
NB-IoT- Narrow Band- Internet of Things TPR- Track Point Relay

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