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Mitigation of Electromagnetic Interference in Rolling stock

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ABSTRACT: A rail transportation systems project has three aspects to it, namely, rolling stock (vehicle), signaling and the power supply. It's a complex system of moving sources of electromagnetic disturbance. The electrical circuits from each of the sub system interact and give rise to a phenomenon called electromagnetic interference (EMI). This is an inevitable process, but if a control plan is not in place for this, this could severely hamper the working of the rail system. This paper discusses about the possible causes for EMI in a rolling stock, measures that can be implemented to reduce it and lastly how it impacts the signaling system.

Keywords: Rolling Stock; Electromagnetic Interferance; Signaling System; Harmonics ; Communication Equipments.

I. INTRODUCTION

A modern rail system draws large traction currents; the purpose of this study paper is to analyze the sources and medium of electromagnetic interference, the processes which are being implemented to achieve electromagnetic compatibility in rail environment. Execution of these measures should help us attain a system which should be able to work accurately as far it's compatibility within the subsystem i.e. rolling stock and electromagnetic environment is concerned and should satisfy contractual requirements at the same time as well as comply with requisite standard. If these measures are executed properly, this may lead to an increase in EMC of the system.

Sources of electromagnetic interference in the rolling stock:

- Track equipment (i.e. primarily signaling equipment)
- Mobile radio
- Mobile phones
- Radio receiver
- Switching phenomenon in vehicles

II. MEDIUM OF ELECTROMAGNETIC DISTURBANCE

A. Radiated interference

The interference energy transferred through space, hence giving rise to unwanted currents and voltages on other devices, interference in close vicinity of the source is also called inductive interference. The interference caused by frequent switching of power electronic devices (for e.g. IGBT, thyristor, GTO) in equipments such as Traction inverter, auxiliary inverter and brake chopper will fall under this category, the medium of transfer can be equipments like motors, brake resistor or isolation transformer. Figure.1 shows the spike in voltage observed when switching phenomenon takes place.

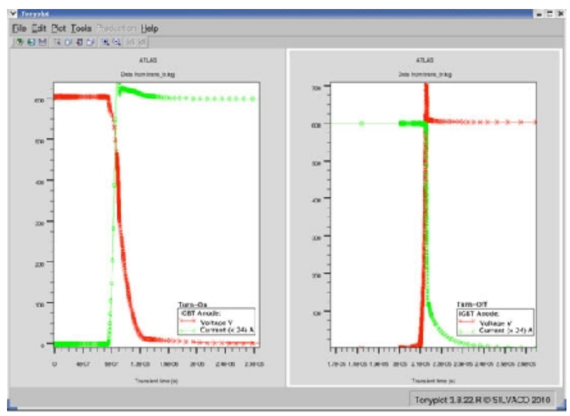

Fig. 1. Spike in voltage during switching phenomenon.

B. Conductive interference

When the interference is transferred to a device through a direct electrical path is called conductive interference. The return current from the rail vehicle can hinder with the efficient working of the track circuits, this type of current is called psophometric current. In Fig. 2, the return current flowing through the running rails in order to provide a return path is the psophometric current.

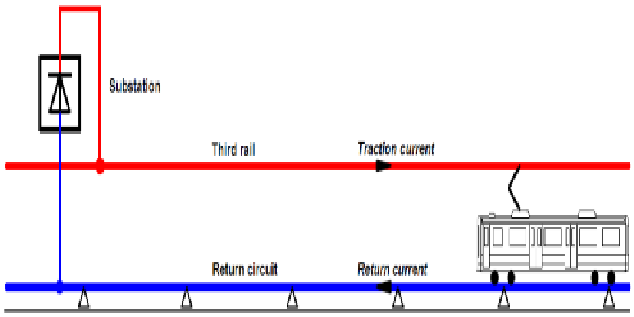

Fig. 2. Psophometric current.

C. EMI by electrostatic discharge

This can be caused by a person wearing insulated shoes, walking on the insulated floor. It depends on the humidity in the air i.e. lower the humidity more is electrostatic discharge and that of person's charge bearing capacity. The train information and communication system is susceptible to loss of information because of it.

D. EMI due to the radio equipment

Electromagnetic field in vicinity of a transmitter can typically be around 100V/m. It is checked that system is free from this phenomenon by making a mobile phone work at 0.4 m from the equipment which is to be tested for EMC.

$$E(d) = \frac{3\sqrt{P}}{d} \quad \ldots (1)$$

The following equation can be verified in Fig. 3.

The strength of the field reduces hyperbolically with respect to distance d, P is the transmitted power.

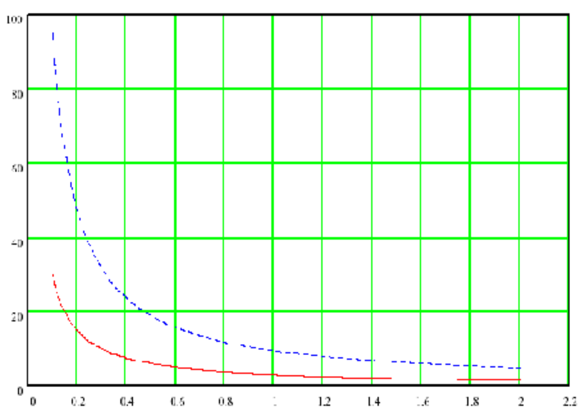

Fig. 3. Graphical verification of Equation1.

III. MEASURES TO CONTROL EMI

A. Grounding

As a part of protective earthing, all equipment bodies are grounded by connecting there surface to the car body, this maintains same potential between the car body and the equipment, hence preventing flow of unwanted currents. This applies to all the parts in light rail vehicles which are conducting current. A few examples of it are traction inverter, auxiliary inverter, HVAC unit, high voltage box, braking resistor etc. Fig. 4 shows how equipment bodies are earthed in a rolling stock. This type of earthing is known as protective earthing.

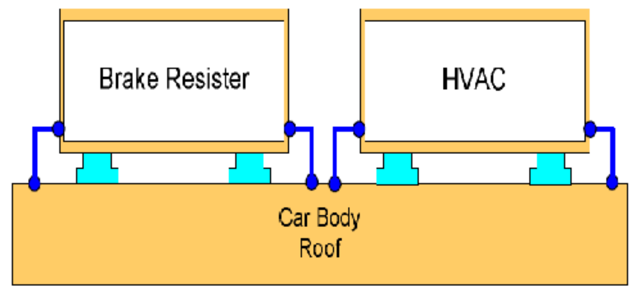

Fig. 4. Equipment bodies earthed in a rolling stock.

Apart from this there is a concept of functional earthing, which ensures that the car body and running rails are at the same potential, hence preventing the flow of stray currents, the return current through the traction motor reaches the copper brushes on the axle, then it goes to the axle of the wheel, through which further it is grounded.

Fig. 5 (on next page) shows a schematic diagram of DC traction system, with the return being functionally earthed to the rails.

B. Shielding

There are four types of cables in the system; they have segregated in the following categories:

- *H category*: Main circuit power wires and it's reflow earth wires i.e. could be typically around 1500 V DC,750 V DC in case of DC supply
- *A category*: These are the high voltage cables mean 't for the auxiliary circuit, they could be 380 V AC
- *B category:* These are 110 V DC or 24 V DC control cables, which are there to form hard wired control logic, 24 V is more prevalent as voltage in network buses like MVB i.e. multi function vehicle bus.

- *C category:* Sensors signal wires and communication wires.

In order to segregate these wires and place them with sufficient clearance, in order to prevent EMI, a separate colour coding is there for all the cables:

- *H type cables are red in colour*
- *A type cables are white in colour*
- *B,C type cables are yellow in colour.*

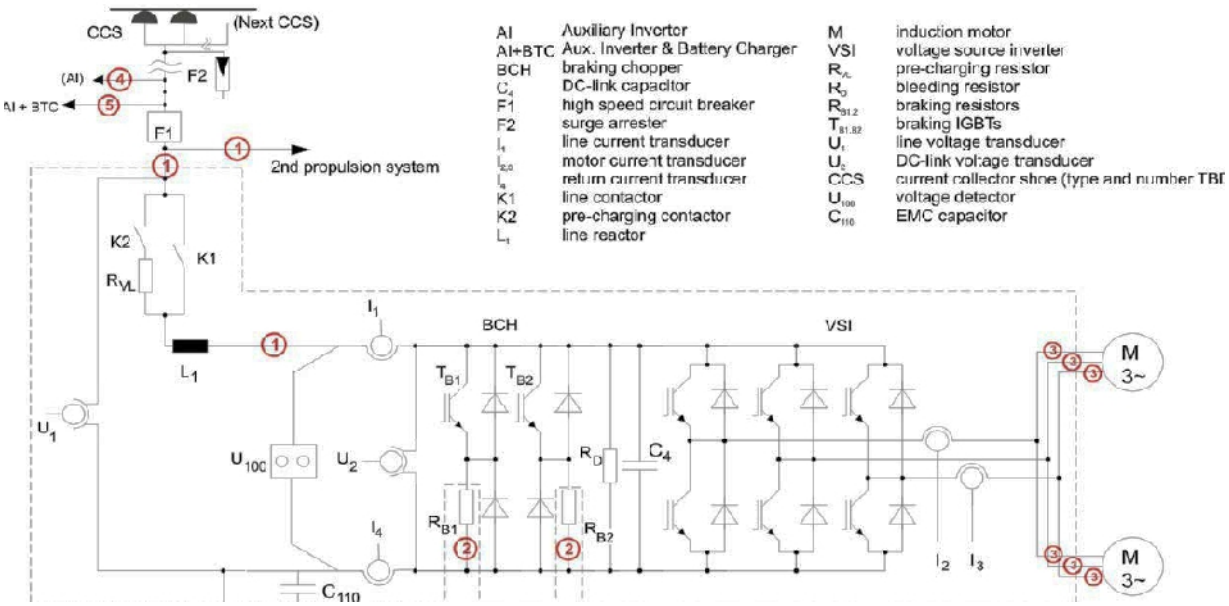

Fig. 5. Schematic diagram of DC traction system.

Table 1. below gives a relative distance which should be maintained between cables of different types, as mentioned above:

Table 1. Relative Distance between cables.

Cable Type	H/A Type	B Type	C Type
H/A Type		0.1 m	0.2m
B Type	0.1 m		0.1 m
C Type	0.2 m	0.1m	

The different type of cables are placed in ducts with partitions, this should be there only if providing clearance is not possible. C type cables are the ones which are most susceptible to EMI, therefore they must be shielded. Wires to the brake resistor must be kept in an aluminum or stainless steel casing. Special perforations must be provided on high voltage cable ducts, in order to facilitate ventilation, as seen in Fig. 6.

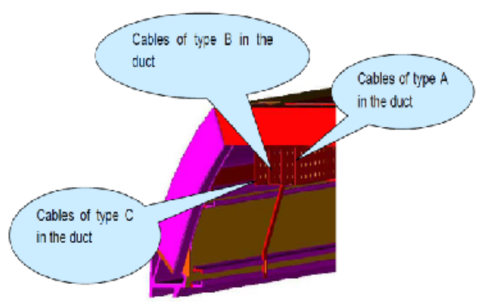

Fig. 6. Different type of cables are placed in ducts with partitions.

Output and input cables should be placed as close as possible, especially power cables.

Plug of network buses such as MVB must have shielding i.e. data communication network must have an EMC plug.

C. Filtering

It is one of the basic ways of reducing EMI, it should be there at the shielding location or it's vicinity. Adequate attention should be given to the fact that there is enough decoupling in the input and output wires.

If a capacitor is being used as a filter, it should be bolted between the shield and the ground. All devices mechanically connected to the inductive loads such as contactors and relays should have transient suppression device. Further mechanical connectors for signaling and control should be equipped with a suitable rheostat.

An overview of the onboard signalling equipment i.e. interface is shown in Fig. 7.

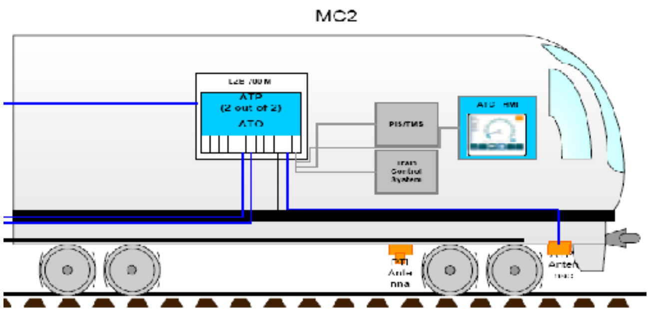

Fig. 7. Onboard signalling equipment.

In a mass transit system in an urban metropolis, a lot of commuter load is expected, to facilitate train movement with a gap of 2 min.

The ATP (Automatic train protection) bit coded telegrams are taken by the ATP antenna, a comparison between the speed requested by ATP trackside unit and actual speed of the train is done, using the feedback given by OPG(odometer pulse generator), this comparison is done by an onboard AT0 computer. The error is given to the controller which in turn facilitates the reduction in error. The human machine interface on the driver's panel is interfaced with the ATO computer. If the computer detects crossing over of a stopping point, immediately emergency brakes are applied. Figure.. 7 gives us an idea, how this is done.

IV. HARMFUL EFFECT OF EXCESS RETURN CURRENT

Automatic train protection (ATP) is used as a means to maintain the requisite headway between trains, for each track section which train is entering a telegram is to be given to the train using bit coded frequency modulated signals which are sent to AFTC i.e. the audio frequency track circuit, which is detected by the ATP antenna of the train as they are sent via the running rails.

These same running rails are used to provide a return circuit for the traction currents, hence when the traction currents interfere with the frequency modulated ATP telegram signal, the telegram which was meant to be sent to the train might get altered, hence can have disastrous consequences. However AC traction currents can be held as the culprit for this phenomenon. Therefore a proposition in this context has been made below in Table 2. below gives the permissible limits of AC traction currents at particular frequencies for various track circuit frequencies.

Table 2. Permissible limits of AC traction currents Relative.

4.75kHz Track circuit frequency	5.25 kHz Track circuits frequency	5.75kHz Track circuit frequency	**6.25** kHz Track circuit frequency	9.0 to 17.0 kHz Track circuit frequency
100 mA at f = 100 Hz to 170 mA for f = 300 Hz	100 mA to f = 100 Hz to 170 mA to f = 300 Hz	100 mA to f = 100 Hz to 170 mA to f = 300 Hz	100 mA to f = 100 Hz to 170 mA to f = 300 Hz	100 mA everywhere with f = 300 Hz

Another possible hazard that can be caused by excess return current is that it can lead to false picking up of track circuits. A track circuit is demarcated by S bonds, which has got audio frequency currents flowing through it. There are tuning units on each of the S bonds, one of it is the transmitter and other is the receiver. When the train enters a section and its axle short circuits a track section, the receiver detects a drop in voltage and hence showing that the section is occupied. If the return currents are more than a particular amount, the track section may show "vacant" status, despite of it being occupied.

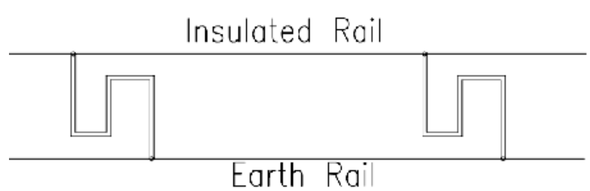

Fig. 8. Vacant status.

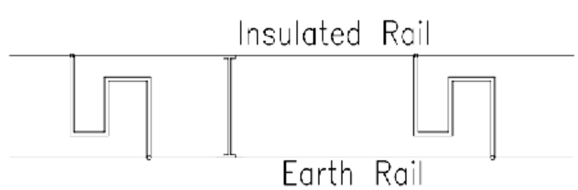

Fig. 9. Occupied status.

V. PROPOSED MITIGATION TECHNICES

A. Proposition to reduce harmonics in return current

To reduce the high frequency AC emissions out of traction inverter a capacitor can be employed between the DC output and ground. In a DC system where in the return currents are in DC along with some harmonics due to switching phenomenon in the IGBT based PWM inverter.

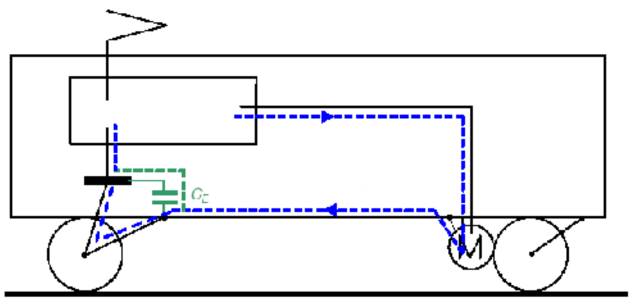

Fig. 10. Technique to reduce harmonics using capacitor.

Now, for DC current the capacitor is in steady state, hence it's open, whereas for AC currents it acts as an alternate path, hence preventing it from going into the running rails. Thereby mitigating a potentially dangerous interference between return currents and ATP telegrams, which are also using running rails as the transfer medium.

B. Suggestions for Signaling and communication equipment

The alternating current portions of the traction currents in the running rails is main interference source for the transmission function of the automatic train protection

- The receiver antenna should be kept away from potential EMI sources, whereas the antenna location of the transmitter should be kept away from the equipment susceptible to EMI
- For effective implementation of EMC measures with signal and communication, it has to be worked out closely with supplier of those equipments.

C. Suggestions for preventing track circuits from showing false pick up

- Running rails are constituted of two parallel rails, the insulated rail and the earth rail, a potential of around 5 V is maintained, in order to facilitate proper working of track circuits, the track is bolted on to the plinth using shear connectors, if the shear connectors of insulated rail are in contact with the steel bars inside the plinth, it could lead to earthing of insulated rail, hence would lead to it showing false "occupied" status for track circuits. Therefore it should be thoroughly checked that shear connectors are not in contact with the steel bars inside the plinth, before casting of the plinths with concrete. Please see Fig. 10.

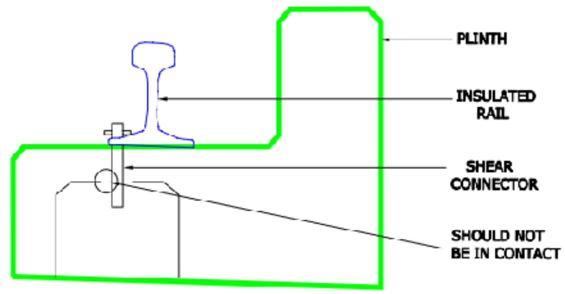

Fig. 11. False "occupied" status for track circuits.

- Secondly, in turnout zones or areas having synchronizing loops or start up loops which on their interaction with track circuits can produce EMI, so in order to control it, we provide plastic clippings in the steel bars inside the plinth. If we look at cross sectional view of the plinth, it is made of intersections of horizontally and vertically placed steel rings, wherever these rings intersect, plastic clippings are placed in order to prevent the flow of redundant currents. The area which forecasted to be prone to such phenomenon is selected during time of construction and is called clipping area. The locations for the clips have been identified in Fig. 11.

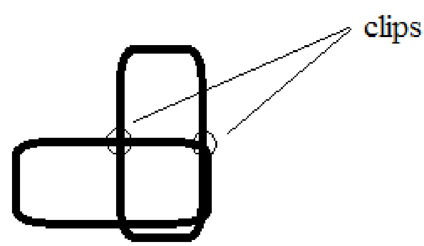

Fig. 12. Locations for the clips.

- Thirdly, no two consecutive track circuits should not be using same frequencies as this can lead to false interpretation of track vacancy status.

VI. CONCLUSION

Majority of measures suggested in the paper, are not having high cost implications, it's only that an awareness in it's context has to be spread and moreover, considering the proliferating rider-ship of rail transport all round the world, increasing concerns about safety and quality, it becomes all the more important for us to apply these measures, Since, it's better to be safe than sorry.

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