Truck circuits diagnosis for railway lines equipped with an automatic block signalling system

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Abstract. This work presents a diagnosis method for detecting track circuits failures on a railway traffic line equipped with an Automatic Block Signalling installation. The diagnosis method uses the installation’s electrical schemas, based on which a series of diagnosis charts have been created. Further, the diagnosis charts were used to develop a software package, CDCBLa, which substantially contributes to reducing the diagnosis time and human error during failure remedies. The proposed method can also be used as a training package for the maintenance staff. Since the diagnosis method here does not need signal or measurement inputs, using it does not necessitate additional IT knowledge and can be deployed on a mobile computing device (tablet, smart phone).

1. Introduction
Most failures of the railroad traffic security installations (especially traffic command and control) are due to specific component breakdowns. Other failures are due to poor maintenance work. No matter the failure cause, these lead to train traffic delays and possibly traffic events.

To identify and diagnose failures of the track circuits several methods can be applied: electric models [1], control and diagnosis equipment [2-4], neuro-fuzzy systems, neural networks [4-6].

Currently, when a track circuit is faulty, the traffic manager that notices the malfunction, notifies the maintenance staff. They, in turn, must travel to the damage location (which often is tens of kilometres away), observes the state of the installations, performs measurements and established the cause of the damage. In all this time, train traffic can only happen with reduced speed or not at all.

The failure diagnosis time significantly depends on the theoretical and practical abilities of the maintenance staff. Since they often act in stress conditions to which the weather conditions are an important factor, the diagnosis method we propose here can offer substantial help.

The method we propose in this work is based on diagnosis charts created by us, and then transposed into a software package of a diagnosis software. The user of the software does not need IT know-how, as the program has a friendly, simple, question based interface. The answers given by a user to the series of questions shown by the software lead to a quick identification of the damage cause.
2. Track circuits on an ABS block

On most railroad blocks equipped with electrodynamic centralized installations (CED in Romanian) the train traffic between two consecutive stations is commanded and controlled by an Automatic Block Signalling installation (ABS). The main components of an ABS installation are:

- Track circuits which control the rail line integrity and the occupation state of the various sectors (by rolling stock for example) [7];
- Light signals which are used to communicate traffic orders to the train operators on locomotives. These signals allow or forbid train passage from one sector to the next [8, 9];
- Control and command circuits that control the ABS installation, including its traffic orientation [10-12].

Lighting signal and ABS orientation control and command diagnosis have been presented in other works [10-12].

Track circuits power supply is done in the reverse direction to the traffic direction, such that, a circulating train will always meet the reception part of the track circuit. When the ABS installation is re-oriented, the reception part becomes the powering component, while the powering component becomes the receiving one. The installation re-orientation is realised by the orientation directing relay clamps (X-D or Y-D) powered by the directing relay, D.

Figure 1 presents the power up schema for four track circuits (Y1-AD, Y2-AD, X2-AD, X1-AD) on an ABS equipped line, when the traffic direction is in the X direction (X-oriented). Each signal box (DS on Fig. 1) is outfitted with power up components (A) for a receiving and track circuit (R) for the neighbouring track circuit.

![Figure 1. Powering mode for ABS track circuits](image1)

Figure 2 presents the powering schema for the track circuits on an ABS block. Each ABS track circuit is powered from the central post with two voltage levels:

- 220 V/75 Hz to power up the signal boxes and some of their equipment;
- 110 V a.c. to power up the code transmitting relays, which are placed in each signal box.

![Figure 2. Power supply block scheme for the ABS track circuits](image2)
Figure 3 presents the powering scheme for the double wire X1-AD track circuit.

To supply the power to the track circuits two codes are sent, one after the other, with a 0.22-0.23 s offset. The two codes form the sequences which successively power up each track circuit. Thus, if the
Y1AD circuit is powered up in the first sequence (S1), the Y2AD track circuit is powered in the second sequence (S2), while the X2AD track circuit is powered in the first sequence (S1). Each sequence has a 0.345 s long power impulse, followed by a 0.12 s pause [7].

The static closing switch, CS, controlled through the impulse transmitter relay, TS, powers up with pulsating 220 V the transformer’s X-TA primary. The limiting coil, LC, limits the receiving circuit current when the track circuits are shunted.

Regulating the power supply voltage is done through the secondary winding plugs of the X-TA voltage reducing transformer and through the 2.2 Ω resistor on the power supply side. The voltage level is regulated depending on the ballast insulation resistance value, type of cross ties, and the track circuit length, such that the voltage measured in the track lines at the receiving end is at least 0.6 V pulsating d.c.

The role of the joint coils is to ensure that the traction current retour passes from one track circuit to a neighbouring track circuit.

When the track integrity is ensured, for the whole length of the track circuit, the voltage injected into the track lines at the power supply end is received through the joint coil and of the Y-TAR voltage step-up transformer.

Since the traction current retour voltage functions at 50 Hz we must use a track filter, F.C. This will allow the 75 Hz control voltage to pass and will stop the 50 Hz frequencies as well as their superior harmonics.

The F.C. output voltage is passed to the impulse relay, CI, which works in the received pulsing rhythm.

The integrity of the isolating coils separating the track lines of a track circuit from the neighbouring track circuits is controlled by the impulse decoding relay (Figure 4). The transmitter relay T contacts, working in a different sequence than the CI relay’s sequence, power the G relay only when the isolating joints are in a corresponding state.

When an isolating joint is damaged, the two sequences overlap, which disables the decoding relay and the track relay will be de-energized.

3. Diagnosis charts for ABS track circuits and the CDCBla Software
All ABS track circuits are controlled by the command apparatus in the two adjacent train stations. For the situation depicted in Figure 1 the Z1AD and Y2AD track circuits are controlled from the first station, while the X2AD and X1AD track circuits are controlled from the next station.

The main track circuit defects cases occurring are:
- One track circuit is damaged;
- All ABS track circuits are damaged;
- Half the ABS track circuits are damaged.

Figure 5 presents the diagnosis chart for the case where one track circuit is not working as expected and the ABS installation is X-oriented.

The ABS installation that defines how the track circuits function, can be either X-oriented (train traffic away from Bucharest) or Y-oriented (train traffic towards Bucharest) [9-10]. A quick track circuit failure diagnosis can be correctly done only by explicit installation orientation and observation of the defect state depending on the ABS orientation. This is possible because the same apparatus ensures both the receiving and the power supply for different track circuits (e.g. power supply to Y1AD when the ABS installation is X-oriented and power supply for X2AD when the installation is Y-oriented).

Figure 6 presents the diagnosis chart for situations where one track circuit is malfunctioning but only when the installation is Y-oriented.
The charts presented in the previous figures were used to create the CDCBla software, with the use of Visual Basic.Net environment. Figure 7 shows a screenshot taken during a run of the software package.

**Figure 6.** Diagnosis chart for cases when a track circuit malfunctions only when the ABS installation is Y-oriented

**Figure 7.** CDCBla software screenshot
Figure 8 depicts the diagnosis charts for the situation where, independent of the installation orientation, the same track circuit is not working. To facilitate understanding this diagram, we consider that the ABS is X-oriented, that is the orientation relay, X-D, is powered up, and the Y-D orientation relay is powered down.

**Track circuit failure, regardless of the ABS orientation**

1. Are there at least 5 V a.c. pulsating (correct code) at the C reglet terminals in the signal box of the track circuit?
   - NO
   - YES

2. Are there at least 5 V a.c. pulsating (correct code) at the (II1-III1) terminals of the X-TAR transformer?
   - NO
   - YES
   - 10 A fuse is interrupted;
   - 2.2Ω resistor is damaged;
   - Interrupted circuit between the C reglet and the secondary winding of the X-TAR transformer.

3. Are there at least 100 V a.c. pulsating (correct code) at the (I1-I1) X-TAR transformer terminals?
   - NO
   - YES
   - Damaged X-D relay contacts.
   - X-TAR transformer is damaged.

4. Are there at least 0.6 V a.c. pulsating (correct code) in the track lines at the receiving end?
   - NO
   - YES
   - Interrupted track lines;
   - Interrupted conenctions;
   - Imperfect contacts between the conenctions and the tracks.

5. Are there at least 0.6 V a.c. pulsating (correct code) at the (II1-III1) terminals of the Y-TAR transformer?
   - NO
   - YES
   - 10 A fuse interrupted;
   - 2.2Ω resistor damaged;
   - Interrupted circuit between the C reglet and the secondary winding of the Y-TAR transformer.

6. Are there at least 0.6 V a.c. pulsating (correct code) at the (I1-I1) Y-TAR transformer terminals?
   - NO
   - YES
   - Damaged Y-D relay contacts.

7. Are there at least 0.6 V a.c. pulsating (correct code) at the (31-71) Y-D (X-D) relay terminals?
   - NO
   - YES
   - Interrupted circuit between the Y-TAR transformer secondary winding and the Y-D relay.

8. Are there at least 0.6 V a.c. pulsating (correct code) at the joint coil terminals?
   - NO
   - YES
   - Damaged cords;
   - Improper contacts between the cords and the track lines.

9. Are there at least 0.6 V a.c. pulsating (correct code) at the joint coil reglet terminals?
   - NO
   - YES
   - Joint coil damaged.

10. Are there at least 5 V a.c. pulsating (correct code) at the power supply end?
    - NO
    - YES
    - Damaged cords;
    - Imperfect contacts between the cords and the track lines.

11. Are there at least 5 V a.c. pulsating (correct code) at the joint coil terminals?
    - NO
    - YES
    - Damaged X-TAR transformer.

12. Are there at least 0.6 V a.c. pulsating (correct code) at the joint coil terminals of the Y-TAR transformer?
    - NO
    - YES
    - Interrupted power cable between the signal box and the BJ.

13. Are there at least 5 V a.c. pulsating (correct code) at the (I1-I1) Y-TAR transformer terminals?
    - NO
    - YES
    - Damaged X-TAR transformer.

**Figure 8.** Diagnosis chart for track circuit failures for both ABS installation orientations
The chart presented in Figure 6 considers cases where the maintenance staff first travels to the power supply component of the damaged track circuit.

Because the latter two failures we described are caused, mainly, by failures of the power systems, we plan to analyse and describe these cases in another article.

4. Conclusions
With the design of the diagnosis charts and the CDCBla software presented in this work, a user of this software needs to answer successive questions shown by the program. At the end of the series of questions the reason for the installation failure is presented to the maintenance staff.

The work presented in this paper contributes to the diagnosis of traffic safety installations of type CED-CR2 on traffic lines equipped with ABS installation by significant reductions in diagnosis and remedy times, eliminating wrong decisions that may be made by maintenance staff in the diagnosis phase.

References
[1] Debiolles A, Oukhellou L, Aknin P and Denoeux T 2006 Track circuit automatic diagnosis based on a local electrical modelling, \url{http://www.railway-research.org/IMG/pdf/492.pdf} [last retrieved: 25.07.2017]
[2] Oukhellou L, Debiolles A, Denœux T and Aknin P 2010 Fault diagnosis in railway track circuits using Dempster-Shafer classifier fusion, ScienceDirect, Engineering Applications of Artificial Intelligence 23(1) 117-128
[3] Ishima R, Fukuta Y, Matsumoto M, Shimizu N, Soutome H and Mori M 2008 A New Signalling System for Automatic Block Signal between Stations Controlling through an IP Network, \url{http://www.railway-research.org/IMG/pdf/o.3.4.2.1.pdf} [last retrieved: 25.07.2017]
[4] Gillich N, Potoceanu N, Gillich G R, Raduca M and Chioncel C P 2008 Intelligent system for the control of ambiental parameters in hi-tech workplaces, Proceedings of the 6th International Conference of DAAM Baltic Industrial Engineering PTS 1 and 2, Tallinn, Estonia, pp 71-76
[5] Chen J, Roberts C and Weston P 2007 Fault detection and diagnosis for railway track circuits using neuro-fuzzy systems, ScienceDirect, Control Engineering Practice 16 585-596
[6] Tirian G O, Filip I and Prostean G 2014 Adaptive control system for continuous steel casting based on neural networks and fuzzy logic, Neurocomputing 125(Special Issue) 236-245
[7] Piroi I, Spune E, Chioncel C P and Piroi F 2015 Rapid Diagnosis of Track Circuits in a Railroad Station, 9th International Symposium on Advanced Topics in Electrical Engineering ATEE 2015, București, Romania, May 7-9, pp 710-715
[8] Tetsuo T 1999 Signalling systems for safe railway transport, Japan Railway & Transport Review September 44-50, \url{http://www.ejrcf.or.jp/jrtr/jrtr21/pdf/F44_Technology.pdf}
[9] Piroi I, Spune E, Chioncel C P and Piroi F 2016 Computerized Diagnostic of the Red and White Entry Lighting Signal Indications, International Conference on Applied and Theoretical Electricity ICATE 2016, Craiova, Romania, October 6-8
[10] Spune E, Piroi I, Muscai C and Piroi F 2014 ABS Failure Diagnosis Charts for a Blocked CL, International Conference on Applied and Theoretical Electricity ICATE 2014, Craiova, Romania, October 23-25
[11] Spune E, Piroi I, Muscai C and Piroi F 2014 Automatic Block Signaling Installation Failure Diagnosis with LCOBl, International Conference on Applied and Theoretical Electricity ICATE 2014, Craiova, Romania, October 23-25
[12] Piroi I, Spune E, Muscai C and Piroi F 2014 Diagnosis Charts for Regular Inversion Failures of an Automatic Block Signal Installation, International Conference on Applied and Theoretical Electricity ICATE 2014, Craiova, Romania, October 23-25