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Evaluation of Railway Switch Drive Operating Condition Using Control Current Features

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Introduction

Lithuanian railways exploit about 24500 electrical railway switch drives. Their reliability index is not high: fault intensity is about $0.2*10^{-4}$ 1/hour, average repair duration including arrival terms and fault finding is about 48 min. So only for railway switch drive maintenance and repair is spent over 300 working hours per year [1]. In most cases faulty switch drives are detected during the route preparation or cancellation procedures and this may increase probability of traffic disturbance.

A strong attention is paid on maintenance of railway switch drives but the efficiency of preventive measures is quiet low because of inadequate distribution: both good condition drives and drives with progressing fault are periodically checked by a sequence. For this reason methods to monitor the condition of railway switch drive and to detect faults during the course of drive switching period are required.

There are no automated real–time diagnostic systems for russian–made switch drives in Lithuanian railways [1]. Experimental diagnostic systems are only available in some regions of Russia and they are mostly designed to detect motor coil faults but not to detect mechanical railway switch drive faults such as pollution or springing.

Usually a few parameters of drive current are used to evaluate the condition of a railway switch drive, such as the nature of transition process, steady–state current, drive switching duration, high frequency noise level, periodical impulse or harmonic current component. The steady-state current depends on pollution of the drive and other factors; the high frequency noise is often induced by a rotor brush sparkling or defective drive bearings.

As for today the main diagnostic method is to monitor the drive current strength at station desk [1]. This allows the operator to judge whether the motor is running or stopped, the current strength also indicates that the drive has reached the final position or has stopped due to some obstacle and the movement is unfinished. Modern stations already have digital controllers that generate an alarm if the current strength exceeds the limits. This method is effective when used to detect faulty railway switch drives, but it is quiet subjective when used for diagnostics.

Early researches [1] show that the switch drive operating condition can be evaluated from the drive current shape, but in reality the following limitations were noticed:

– the railway switch drives are situated in different distances from station desk and the cabling effects the control current making the diagnostics complicated;

– stations often use switches of different radii that have different weight, switching time and force applied. In this case parameters of different radii can’t be analyzed using the same model. Each of them must have their own model described.

The analysis above shows that the control current has to be treated as a random process and in this case its identity function may be suitable for diagnostics. The identity function then must meet following rules:

– the identity functions of different but good condition drives must be similar;

– the identity functions of faulty drives or drives with progressing fault must be significantly different from those of good condition drive;

– the identity functions that are caused by particular fault must be similar and the identity functions that are caused by different faults must be significantly different.

Experiment

The railway switch drives that are in use in Lithuanian railways are mostly driven by brushed DC motor with 2 excitation windings – one for each rotation direction.

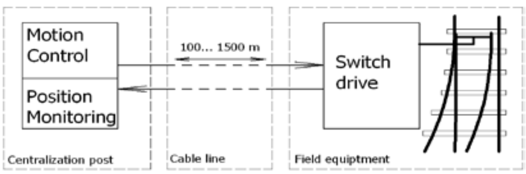

Fig. 1. Structural scheme of railway drive control system

In order to investigate the problem a real–conditions experiment at Lithuanian railways was carried out. The control system at centralization post and switch drive are interconnected using two threads of a cable line. A resistance of 0.5 Ohms was connected in series with switch drive power line to register voltage drop that is proportional to drive's feeding current (the same current is also used for control purposes). The voltage drop was registered using digital oscilloscope.

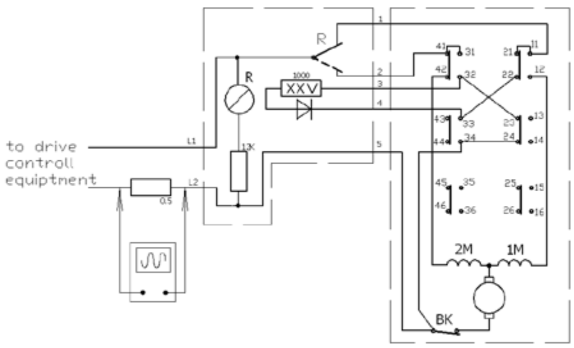

Fig. 2. Scheme of experimental investigation

During the experiment signals of three different classes were registered:

- class A – good condition drive,
- class B – drives with progressing flaws,
- class C – drive that must be inspected due to increased mechanical load.

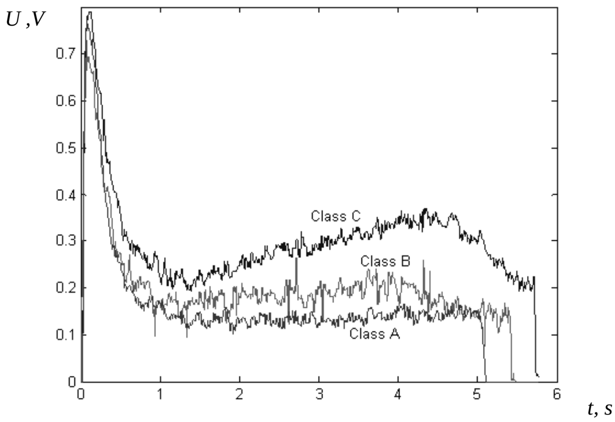

Fig. 3. Switch drive control signals

Often spectrum analysis is enough to investigate signal properties. In our case this analysis didn't give expected results (Fig. 4.), as it didn't reveal specific differences between spectrums of signals from drives of different operating conditions.

Another way to obtain signal classification parameters is signal cepstrum calculation (1)

$$\hat{x} = \frac{1}{2\pi} \int_{-\pi}^{\pi} \log\left[X(e^{j\omega})\right] e^{j\omega n} d\omega . \qquad (1)$$

Next the cepstrum of switch drive control signals was calculated to obtain the information about drive operating conditions (Fig. 5.). In this case this investigation also didn't give expected results.

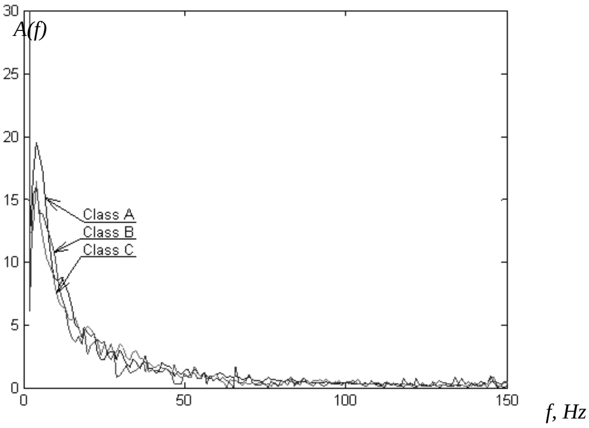

Fig. 4. Results of spectrum analysis

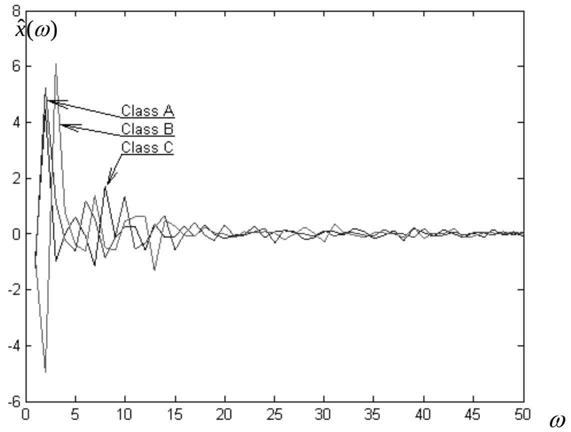

Fig. 5. Results of cepstrum analysis

This analysis shows that nor spectrum, nor cepstrum analysis are not suitable to obtain specific information on railway switch drive operating condition from switch drive control signals.

Suppose, we have several realizations of accidental processes $x_1(t)$, $x_2(t)$, …, $x_n(t)$, which are in defined area *C*, when $t \in [t,\ t+T]$, here is the observation interval (the realization length) and F transformation (operator) exists [2]:

$$\begin{cases} g_1(z) = Fx_1(t),\ when\ z \in [0,b], \\ g_2(z) = Fx_2(t),\ when\ z \in [0,b], \\ \vdots \\ g_n(z) = Fx_n(t),\ when\ z \in [0,b]. \end{cases} \qquad (2)$$

Signal characteristics $g_n(z)$ are in defined areas *C*. Proposition is valid if $x_1(t)=x_2(t)$, then $g_1(z)=g_2(z)$, then, bringing a new variable quantity $v[0,b]$, a metric space is determined as covariance metric which can be used for classification. The characteristics of covariance metric are these:

$$\begin{cases} d(g_1, g_2, \nu) = d(g_1, g_2, \nu), \\ 0 < d(g_1, g_2, \nu) < 1, \\ d(g_1, g_2, \nu) = 0,\ if\ \ g_1(z) = kg_2(z), \\ d(g_1, g_3, \nu) < d(g_1, g_2, \nu) + d(g_2, g_3, \nu). \end{cases} \qquad (3)$$

Two kinds of covariance metrics $d_1(g_1, g_2, v)$ and $d_2(g_1, g_2, v)$ are defined. Covariance functions of signal, which characteristics $g_1(z)$ and $g_2(z) \in C$ and $v \in [0, b]$:

$$\begin{cases} R_{12}(v) = \frac{1}{b}\int_0^b g_1(z)g_2(z-v)dz, \\ R_{21}(v) = \frac{1}{b}\int_0^b g_2(z)g_1(z-v)dz, \\ R_{11}(v) = \frac{1}{b}\int_0^b g_1(z)g_1(z-v)dz, \\ R_{22}(v) = \frac{1}{b}\int_0^b g_2(z)g_2(z-v)dz, \\ R_{12}(v) \le R_{11}(0) \cdot R_{22}(0). \end{cases} \quad (4)$$

Using the intercorrelation function $R_{12}(v)$ makes possible to calculate and evaluate the correlation between the signals of good condition drive g_1 and defectives drives g_2. The obtained identity functions are presented in Fig. 6. As we can see on figure 4, the identity functions of good condition drives (class A) are almost identical. The identity functions of classes B and C vary from class A identity function and also vary between itself. This means that correlation between good condition drive current signal and defective drive current signal can be used in a defective system identification system.

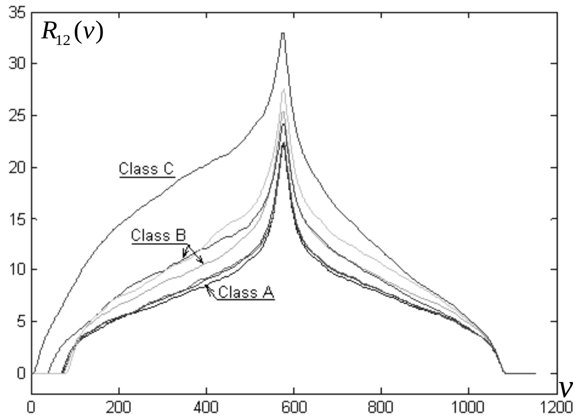

Fig. 6. Intercorrelation identity functions

The identity function $R_{11}(v)$, obtained using the switch drive current signal autocorrelation are also suitable to evaluate informative features [3]. The distances between identity functions of different classes are higher and this means that class attributes in a metric space will be allocated further from each other and won't overlay each other [4].

Other investigated functions, like cepstrum analysis or spectrum analysis didn't give result that might be suitable for signal classification.

To draw a two–dimensional metric space according to results, presented in Fig. 7, the informative points 700 and 950 are selected. To assure the results are trustworthy, one more experiment at Lithuanian railways was carried out using more railway switch drives of different conditions (classes A, B and C). The allocation of experimental results in metric space is presented in Fig. 8.

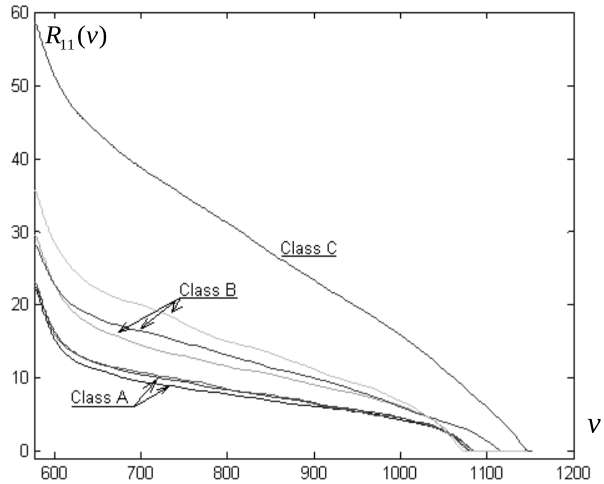

Fig. 7. Autocorrelation identity functions

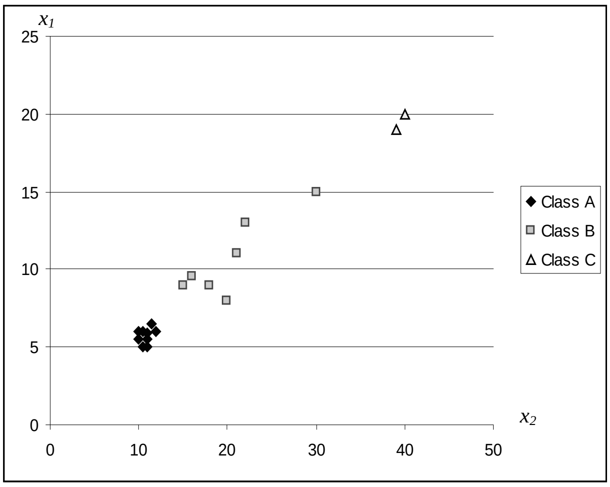

Fig. 8. Distribution of features in a metric space

As we can see from the Fig. 8, the objects that depend to different classes (A, B and C) are located remotely one from another and do not overlay. As the result we can state that identity functions, obtained using signal autocorrelation, provide enough information to evaluate the state of railway switch drives and to sort them into according classes.

In this case to implement switch drive diagnostic system we suggest the control schemes that are present at centralization post, to be supplemented by scheme for control signal measurement and classification (Fig. 9.).

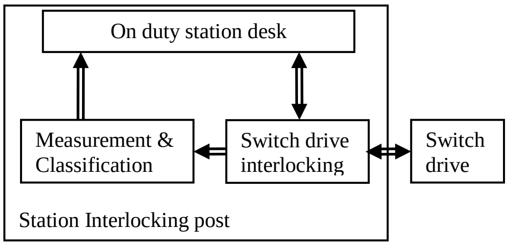

Fig. 9. The structure of a proposed system

Thus it becomes possible not only to inform the station watcher about the technical state of railway switch drives, but also register and save the information diagnostic information for each drive. Using the proposed system makes possible to track changes of state of a drive and notice the evolving flaws. In this case the maintenance can be carried out timely and prevent breakdown of a device.

Conclusions

1. Early researches show that it is erroneous to investigate physical parameters of railway switch drive control signal (switching duration, steady–state current etc.) in order to obtain classifying features due to the influence of cable line parameters.
2. The autocorrelation function is suitable, in this case, for distant monitoring of switch drive state (good condition, faulty, progressing fault).
3. Investigation of signal statistical properties as of random process allows segregating signals of good condition drives and drives with flaws.
4. The distribution of features of experimentally obtained results in a metric space shows that the proposed method of features evaluation is proper to identify good condition drives, faulty drives and drives with evolving flaws.
5. The future investigations should concentrate on verification and revision of classification features in order to classify railway switch drives (their control signals) with different radii (drives that are affected with different load force).

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J. Daunoras, V. Gargasas, A. Knyš. Evaluation of Railway Switch Drive Operating Condition Using Control Current Features // Electronics and Electrical Engineering. – Kaunas: Technologija, 2010. – No. 10(106). – P. 71–74.

This paper presents the results on investigation of railway switch drive operating condition using control current features. The problem is formulated in introduction – now operator subjectively judges the state of the drive by a control current strength. A structural scheme and a description of drive control system are presented. The results of experiment at Lithuanian railways that represent switch drives of three different conditions (good, with progressing fault and faulty) are presented. The investigation of control current features was carried out and, as the result, the method that allows automatically and in real–time classify drives of different operating conditions is presented. Also the proposed structure of modernized centralization post and conclusions are given. Ill. 9, bibl. 4 (in English; abstracts in English and Lithuanian).

J. Daunoras, V. Gargasas, A. Knyš. Geležinkelio iešmo pavaros būklės analizė pagal valdymo srovę // Elektronika ir elektrotechnika. – Kaunas: Technologija, 2010. – Nr. 10(106). – P. 71–74.

Straipsnyje pateikiama nuolatinės srovės geležinkelio iešmo pavaros būklės analizė pagal valdymo srovę. Problema aktuali tuo, kad dabar apie iešmo pavaros būklę operatorius subjektyviai sprendžia tik pagal pavaros perjungimo srovės dydį arba indikacinę lemputę. Pateikiama pavaros valdymo sistemos struktūrinė schema, jos veikimo principas. Pristatomi eksperimentinio tyrimo, atlikto realiomis sąlygomis AB „Lietuvos geležinkeliai“, rezultatai, kurie atspindi tris iešmo perjungimo pavarų būkles – gerai veikiančią, reikalingą priežiūros ir remontuotiną. Atliktas iešmo pavaros valdymo srovės požymių tyrimas ir parinktas signalų apdorojimo metodas, leidžiantis automatiškai ir realiu laiku klasifikuoti skirtingų būklių iešmo pavaras. Straipsnio pabaigoje pateikiama siūlomo modernizuoto centralizacijos posto struktūra ir apibendrinančios išvados. Il. 9, bibl. 4 (anglų kalba; santraukos anglų ir lietuvių k.).