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PARASITIC FIELDS (STRAY CURRENTS) AND THEIR DIRECT AND ALTERNATING COMPONENTS FROM THE POINT OF VIEW OF CORROSION

PARAZITNÍ POLE (BLUDNÉ PROUDY) A JEJICH STEJNOSMĚRNÁ A STŘÍDAVÁ SLOŽKA Z POHLEDU KOROZITY

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Abstract

The portfolio of tasks that the geophysical workplace solves also includes a basic corrosion survey of construction sites, consisting of measuring the size of stray currents, determining the size of specific resistances and evaluating the degree of aggressiveness of the investigated rock environment. The findings can significantly affect the extent of the necessary anti-corrosion measures, and thus the costs of the final price of the planned construction. Most researchers (geophysicists) have a well-established practice that we measure the direct current field of stray currents (or the field that we consider to be quasi-direct current). Also the professional literature in the field of corrosion stated that corrosion caused by DC current sources is essential and alternating fields are less significant. Recently, however, the opinion on 50 Hz sources has changed, they are considered potentially significantly dangerous, and some clients therefore also require detection and evaluation of the alternating array. The practice of our sales department also shows that some clients also demand monitoring of electromagnetic fields up to high frequencies (kHz or more), which is related to the issue of occupational hygiene or the fear that intense electromagnetic fields could interfere with sensitive computer technologies. We believe that the emerging trend is not accidental and that there is a vacancy on the market for professionally and hardware-prepared geophysical workplaces.

Abstrakt

Do portfolia úkolů, které řeší geofyzikální pracoviště, patří také základní korozní průzkum stavebních lokalit, sestávající z měření velikosti bludných proudů, zjišťování velikosti měrných odporů a vyhodnocení stupně agresivity zkoumaného horninového prostředí. Zjištěné poznatky mohou významně ovlivnit rozsah potřebných protikorozních opatření, a tím i náklady na konečnou cenu připravované

stavby. Většina řešitelů (geofyziků) má zažitou praxi, že měříme stejnosměrné pole bludných proudů (resp. pole, které považujeme za kvazi stejnosměrné). Také odborná literatura z oboru korozity uváděla, že korozita, která je způsobována stejnosměrnými zdroji proudů, je zásadní a střídavá pole jsou méně významná. V poslední době se však názor na zdroje 50 Hz mění, jsou považovány za potenciálně významně nebezpečné a někteří klienti tedy požadují i detekci a vyhodnocení střídavého pole. Z praxe našeho obchodního oddělení se také ukazuje, že někteří klienti poptávají i sledování elektromagnetického pole do vysokých frekvencí (kHz i více) což souvisí s problematikou hygieny práce nebo s obavou, že intenzivní elektromagnetické pole by mohlo rušit citlivé technologie výpočetní techniky. Domníváme se, že nastupující trend není náhodný a pro odborně a hardwarově připravená geofyzikální pracoviště se zde otvírá volné místo na trhu.

Keywords

Parasitic field, stray current, direct current, alternating current, corrosion

Klíčová slova

Parazitní pole, bludný proud, stejnosměrný proud, střídavý proud, koroze

1 Introduction and the basic legislation and literature in the domain of stray currents

The area of services provided by the geophysical workplace also includes the implementation of basic corrosion surveys. This means that the occurrence of stray currents propagated through the rock environment is monitored and the measured data are then evaluated from the point of view of the danger of electrochemical corrosion. For more details on the topic, see lit. Bárta 2023., or more broadly also Bárta 2010, Karous 1989, Rozsypal 2008. So far, most of the geophysicist have encountered the issue of stray currents propagated from DC sources in practice. Recently, however, attention has also been focused on alternating electric fields, namely 50 Hz, but also higher frequencies.

In the Czech Republic, respect for the following standards and methodological guidelines is required:

ČSN (Czech State Standard) 03 8375: Protection of metal pipes laid in soil or water against corrosion.

ČSN 03 8372: Principles of corrosion protection of non-linear devices stored in the ground or in water.

ČSN 03 8365: Determination of the presence of stray currents in the ground.

EN (European standard) 50162: Protection against corrosion by stray currents from direct current systems.

TP 124: Technical condition of the Ministry of Transport. Basic Protective Measures to Limit the Impact of Stray Currents on Bridge Structures and Other Concrete Structures of Roads

METHODOLOGICAL INSTRUCTION of the Ministry for Transport: Documentation of electrical and geophysical measurements of concrete bridge structures and other concrete structures of roads.

SŽ (Správa železnic) S13: Protective measures to limit the impact of stray currents for railway constructions.

ČSN EN ISO 18086: Corrosion of metals and alloys – Determination of AC corrosion – Protection criteria.

ČSN EN ISO 18086 is probably the start normative document that those interested in measuring of the 50 Hz field. ČSN has not yet been translated into Czech.
GOVERNMENT REGULATION No. 291/2015 Coll: Government Regulation on Health Protection against Non-Ionizing Radiation.

To assess the relationship between the determined current density of the parasitic field propagating through the rock environment and its classification according to the degree of corrosion hazard, the table given in ČSN 03 8375 or ČSN 83 72 can be used, see Table 1 below.

Tab. 1 Risk of corrosion according to ČSN 03 8372

Resistivity [Ωm]	**Current density J_p [mA/m^2]**	**Corrosivity characteristics**	**Degree of corrosiveness**
more than 100	less than 0.0001	very low	I
50 - 100	0.0001 – 0.003	medium	II
23 - 50	0.003 – 0.1	increased	III
less than 23	more than 0.1	very high	IV

The assessment of the risk of corrosion is based on the determined current density of the stray current field J_p [mA/m^2] and the magnitude of the determined specific resistances [Ωm]. The calculated values are compared with the relevant standards (ČSN 03 8372).

In the technical guideline of the Ministry of Transport TP 124, the relationship between the current density J_p, corrosion and the proposal for corrective measures is addressed in a special Annex 8. Mutual relations are shown in Table 2, see below.

The regulation of the Railway Administration SŽ S13 uses a similar evaluation as the Ministry of Transport. Only for corrosion degree 4, the upper limit of current density is already 1 mA/m^2 (for TP 124 it is 3 mA/m^2).

Alternating current (AC) can cause corrosion, especially due to stray currents, which, due to its periodic nature and changing direction, cause repeated electrochemical reactions and degradation of the metal. Unlike direct current (DC), where ions are systematically displaced and corrosion occurs primarily at one electrode, alternating current can cause damage to both electrodes because the direction of the current is constantly changing. This initial situation complicates the study of corrosion phenomena arising in alternating electric fields and it would be desirable for geophysicists specializing in basic corrosion exploration to deal more with this issue. There is not much available literature and practical experience yet, which practically describe the behaviour of an alternating current field in the contact between a rock medium and building object deposited in the ground. See for example lit. Havlik 2010.

Table 2: Degrees of basic passive protective measures to limit the impact of stray currents (Taken from Technical Conditions TP 124, Annex 8, Table 1)

Basic protective measures, level No.	**Current density [mA/m^2]**	**Implementation of basic measures**
1	less than 0.0001	1. Primary protection according to ČSN EN 206-1 A – without connecting the reinforcement and bringing it to the surface of the structure
2	0.0001 – 0.003	2. Combination of primary protection according to ČSN EN 206-1 and Table 3 and, if applicable, secondary protection according to TP, Article 5.3 B – without connecting the reinforcement and bringing it to the surface of the structure
3	0.003 – 0.1	3. The same ad 2 Plus C – construction measures according to TP, Article 5.4, without connecting the reinforcement and bringing it to the surface of the structure
4	0.1 - 3	4. The same ad 2 Plus D – Structural measures according to TP, Article 5.4, including the connection of reinforcement and its exit to the surface of the structure
5	greater than 3	5. The same ad 4 Plus E – documentation "Electrical distribution and equipment for the control of the influence of stray currents" enabling electrical and geophysical measurements (according to the Methodological Instruction) including the implementation and possible design of the following measures.

2 Example of complex measurement of parasitic currents

The selected example is only intended to acquaint the reader with the approximate scope of the demands of clients who will require comprehensive services in the description of parasitic current fields. A detailed measurement report would lead to a disproportionate scope of the article. In order to meet the demands that some clients are beginning to make, a stable methodology for measuring and, above all, evaluating the work has not yet been developed in some respects. When awarding contracts, the client will have to take into account several times higher price costs than is the case when awarding the "Basic Corrosion Survey" that is common today. A potential supplier (geophysical workplace) will have to expand its standard instrumentation.

The location described here is located in Prague. It is a reconstruction of the original industrial hall. Currently, it is planned to be rebuilt into exclusive apartments (lofts). A drawing of the new building and observation stations ST1, ST2, ST3 and ST4, on which stray currents were measured, is shown in Fig. 1. As the design and construction work is still in progress, the map is only shown schematically and it is not possible to give a more detailed description.

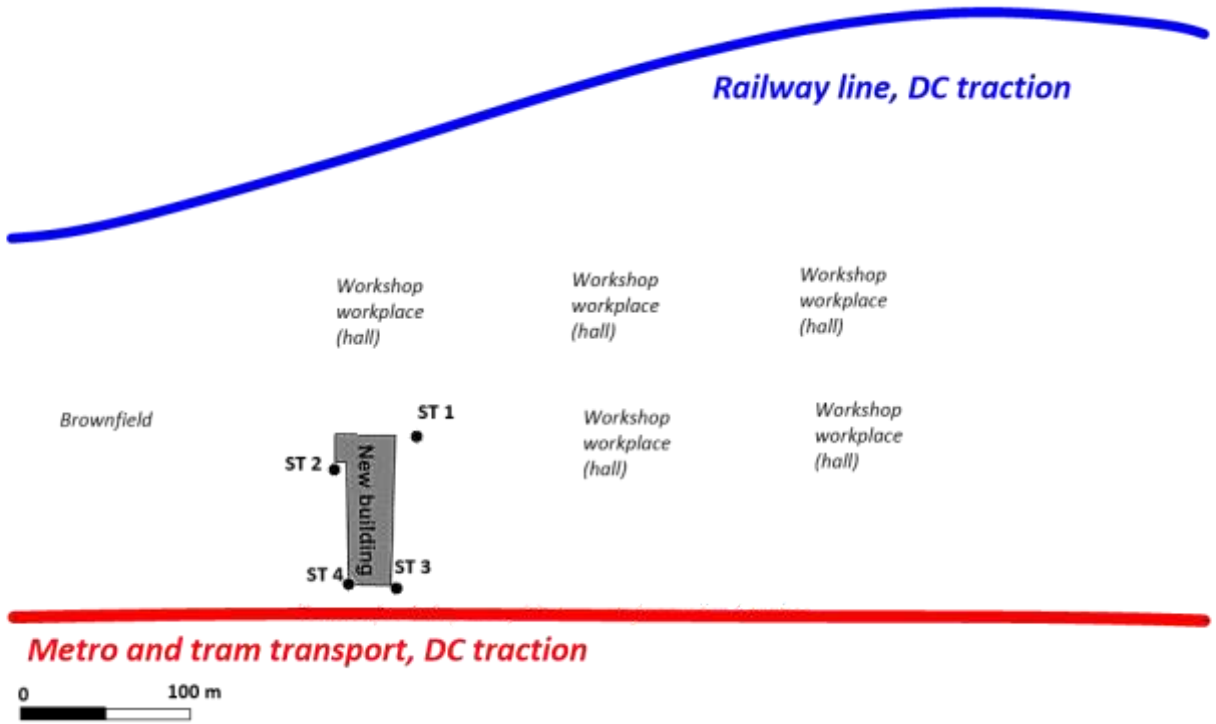

Fig.1 The map scheme with observation station ST 1, ST2, ST3 and ST4

The direct and alternating fields of stray currents were measured at the site. The method of vertical electrical sounding (VES) was used to determine the specific resistances. With regard to the concern that there is an electromagnetic field in the area that could interfere with computer networks, the electromagnetic field was also monitored. The stray current potential gradient was monitored in the time domain using the Blow 2 instrument (see Fig. 2) and the magnitude of the electromagnetic field was measured using the ESM Maschek instrument (see Fig. 3). The ESM 100 simultaneously measures the current and magnetic components of the field in the range of up to 400 kHz. However, the device can also monitor 50 Hz separately. The ability of the instrument to measure the I and H components simultaneously opens up the possibility of using the apparatus as a geophysical instrument for the detection of conductors and structures with higher susceptibility. Vertical electric probes were measured with the geoelectric apparatus of Pešta.

Fig.2 Blow - 2 Stray tracking apparatus

Fig.3 Apparatus ESM Maschek

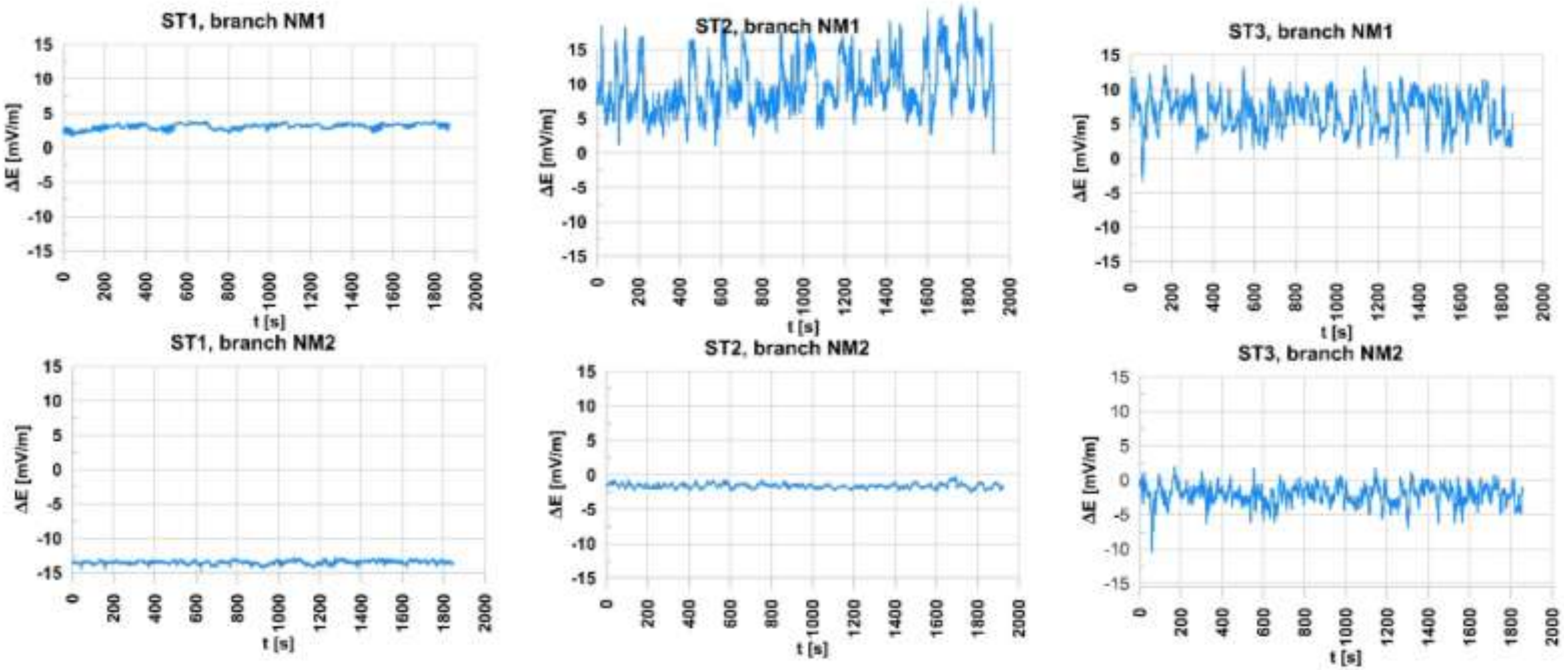

Fig. 4 Gradients potential of stray currents, station ST1, ST2 and ST3 (ST1 has direction of NM1 to the W and NM2 to the S, ST2 has direction of NM1 to the E and NM2 to the S, ST3 has direction of NM1 to the W and NM2 to the N)

Figure 4 shows graphs of potentials gradients from observation stations ST1, ST2 and ST3. Stray currents are significantly reflected on ST 2 (located near the transformer) and ST3 (located near the tram tracks). With regard to the anomalous situation, the network of observation stations was subsequently supplemented by the ST4 station (located near ST3). Here, the potential gradients were measured in direct current (DC) mode and in 50 Hz (AC) mode. The electric fields were monitored for 24 hours (12.3.2025 and 13.3.2025). On the Figure 5 is showed the graph in DC mode. Daily work operation is reflected up to about 18:00 hr (see section which is marked **1**) This is a summary of the resources of carriers and workshop operations. Subsequently, it is possible to monitor the phase of evening and night operation of the underground railway and trams (see section **2**). However, power sources are also in operation between 24:00 and 1:30 hr (maintenance?). This is followed by a phase (see section **3**) with the probable transfer of Metro operation to night rest. However, the calm current field is still fed by resources. At about 5:00 hr (see section **5**), the active operation of the Metro and trams begins. The notes shown here are distinct on the branch NM2. The direction NM1 is not very pronounced.

The current density Jp was calculated at station ST4 for DC 0.0821 mA/m^2 (after correction by a suction effect of 0.246). For AC, the Jp value was 0.123 mA/m^2 (after correction for suction effect 0.369). These values are valid as an average of the entire twenty-four-hour measurement cycle.

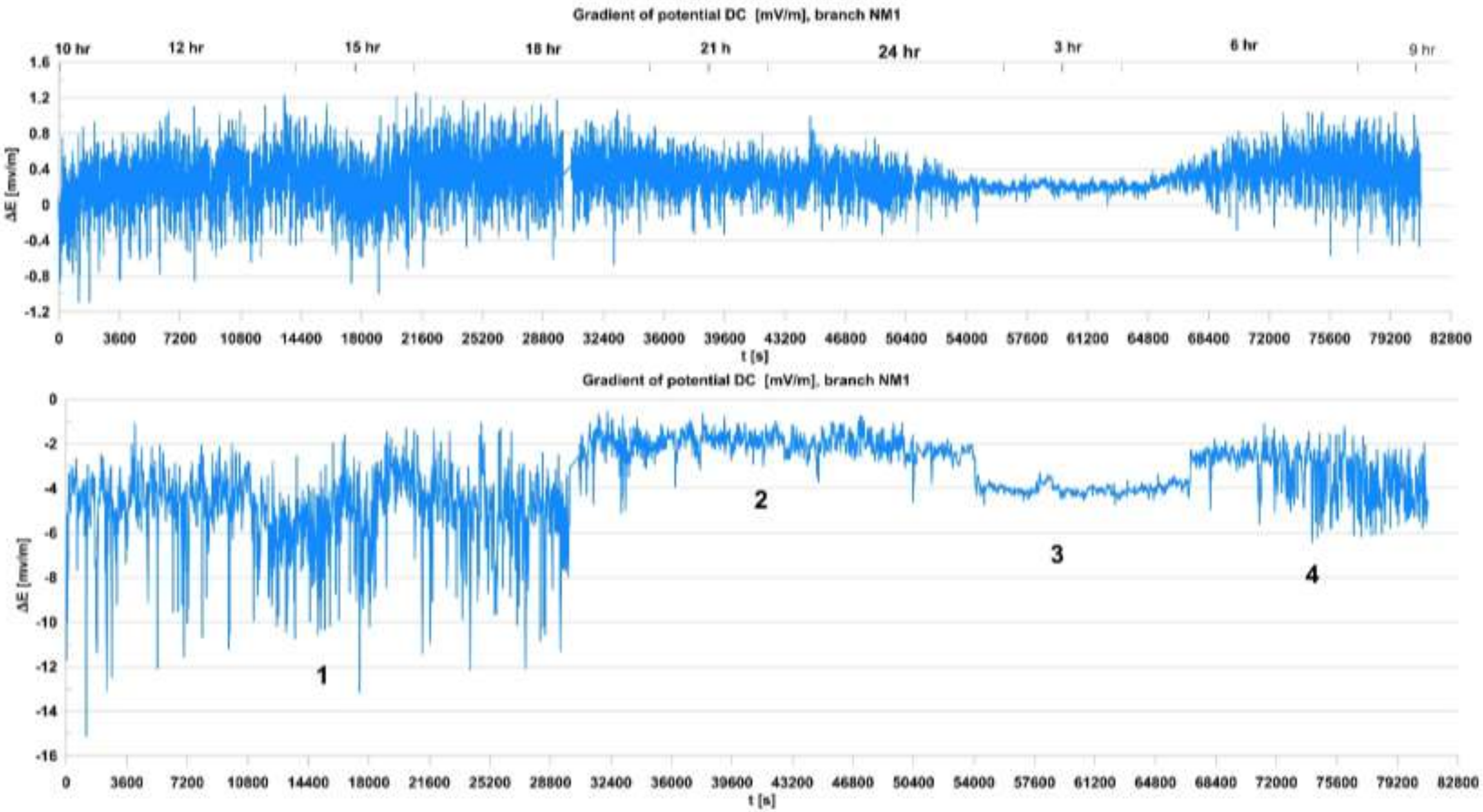

Fig. 5 Gradients potential of stray currents (DC), stations ST4 (the vertical axes were chosen at different scales due to extremely different measured value; branch NM1 has direction to the N and NM2 to the E)

Figure 6 shows the measurement record in AC mode (the day of measurement is the same as in DC mode, see Fig. 5). In AC mode, the period from about 10:00 a.m. to 6:30 p.m. is particularly easy to watch. The extreme course of data on the NM2 branch graph can probably be explained by the fact that it is a manifestation of a nearby strong source that is strongly directionally oriented. The power supply is probably located near our station (we assume some electrical machine in the neigh boring factory).

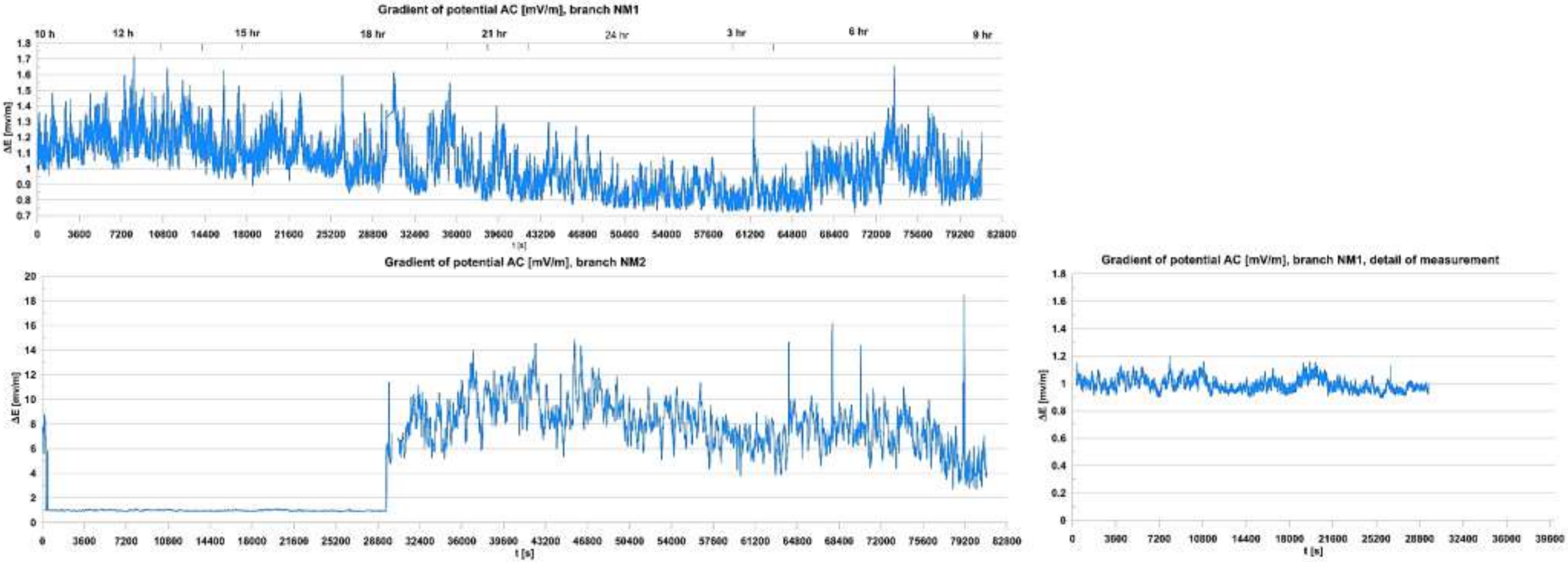

Fig. 6 Gradients potential of stray currents (AC), stations ST4

The equipment (apparatus ESM Maschek) detected frequencies from 50 Hz to 400 KHz (total vector of elmg). Figure 7 presents the measurement of the electromagnetic field (part H and E, total vector of the field) which was measurement from 11. 3. to 12. 3. 2025, on the observation station ST4. The records are close conditional on the daily activities round the observation station. The results of the measurements are not in conflict with the Government Regulation on Health Protection against Non-Ionizing Radiation No. 291/2015 Coll., i.e. the values do not exceed hygienic limits.

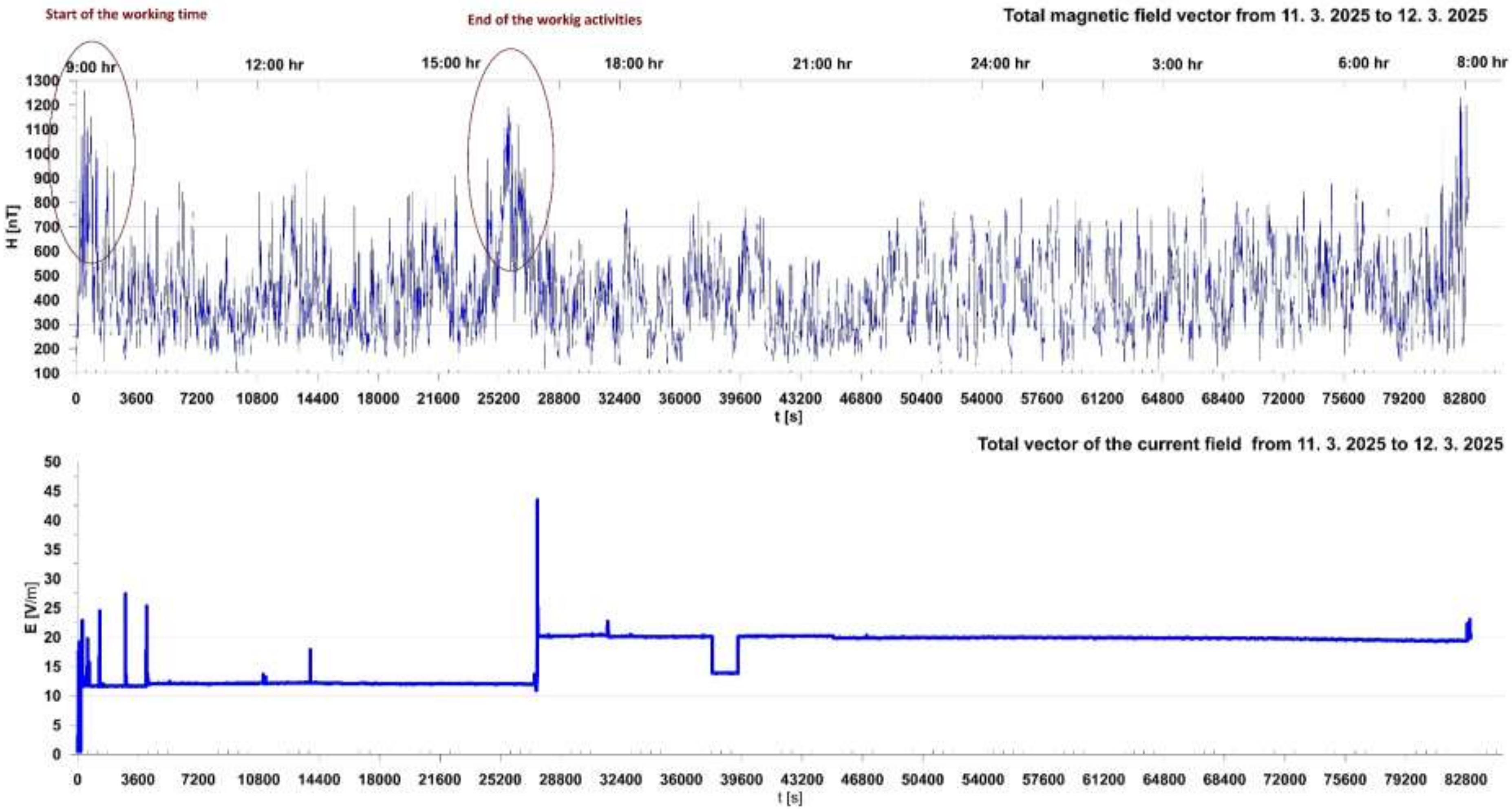

Fig. 7 Electromagnetic fields, part H and E, stations ST4. Measurement from 11. 3. 2025 to 12. 3. 2025

In Figure 8 is presented mix potentials (U_z) of the DC and AC from the station of ST 1 and ST3. Mixed potentials are most often meant potentials of metal reinforcements deposited in the ground, which are measured against the non-polarizable electrode $CuSO_4$. Positive potentials are mostly an indication of incipient corrosion. The measured values of the mixing potential are surprising and may also be due to the fact that the test leads were connected to the wires that were found in the foundation concrete. However, it does not have to be a rigid reinforcement of the foundation. Documentation of the original foundations of the building is not available. We recommend measuring potentials over a longer time series to make them easier to evaluate.

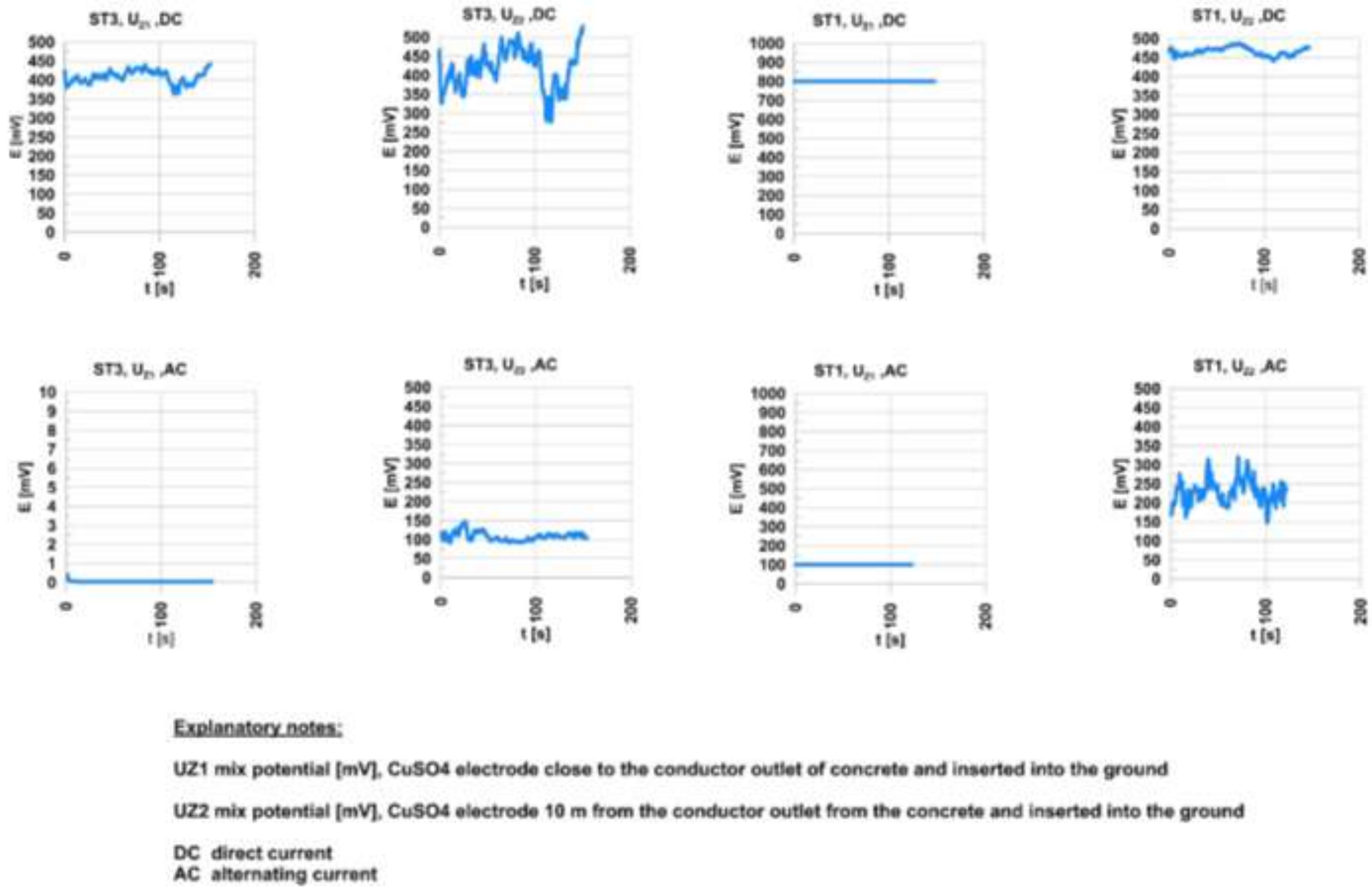

Fig. 8 Graphs of U_z (mix potential) from ST1 and ST3

For the calculation of the current densities JP and the assessment of soil corrosion (the risk of soil corrosion increases with a decrease in specific resistance, see Table 1 in this text), it is necessary to know the resistance ratios of the site well. Engineering-oriented workplaces usually use measurements with a four-electrode system in the Wenner version to determine the size of specific resistances (the result of the measurement is an apparent specific resistance). At geophysical workplaces, measurements using the VES or ERT method are preferred. The output of the measurement is then the knowledge of the actual specific resistances. With regard to the limited financial resources of most projects, the number of resistance curves (VES) performed is often relatively sparse. Therefore, it is recommended to critically evaluate the measured data and generalize them into a representative geoelectric model of the site, which is then used for the calculation of current densities, or for further interpretations. In the case of the locality described here, the geoelectric model was interpreted as follows on the basis of three measured geoelectric probes (VES):

First layer: thickness approx. 1 m, resistivity 760 Ωm, after applying a correction coefficient of 0.6 value 456 Ωm. Second layer: thickness approx. 1 to 10 m, resistivity 90 Ωm when using a correction coefficient of 0.5, value 45 Ωm.

The use of correction coefficients for the conversion of measured resistances to standard values corresponding to average weather is discussed in ČSN 03 8363. The dependence of the natural rock environment on climate is widely known and often studied in geophysics. However, ČSN works with average fixed monthly coefficients, but the fact that each year is climatically different, sometimes even atypical, is not respected. That is why we have built a database in Jeneč (Central Bohemian Region) where we monitor the annual weather development on specific data. Although we will not affect more extreme situations (alpine terrain, rapid local changes), we consider the determination of the correction coefficient based on current measurements taking into account long-term experience to be more reliable than the formal approach set out in the ČSN. The issue mentioned here is a topic for a specialized article and a longer discussion.

3 Conclusion and recommendation

The assessed building is located in an electric field for which the DC component, the alternating component of 50 Hz and the electromagnetic field with higher frequencies have been demonstrated. Field detection was demonstrated at observation stations ST1, ST2, ST3, ST4 by monitoring stray currents in the sense of ČSN 03 8365. The measurement of stray currents was carried out using the BLOW-2 apparatus (OWON B-25T+ meter). The electromagnetic field (up to 400 kHz) was detected using the ESM 100 apparatus (Machek product). From the measured data and terrain reconnaissance, it is clear that the source of stray (parasitic) currents is mainly the operation of the underground railway (Metro) and surface urban electric transport. To a lesser extent, the electrified railway line about 150 m or more away from the construction is involved in stray currents. From a more detailed analysis of the data, it is clear that in the daytime period (7 a.m. to 6 p.m.) the building is also affected by workshop operation from neighboring workshop halls. The significant orientation of the parasitic field is probably also influenced by the current situation on the construction site (possible leaks related to the operation of the transformer station located in the northwest corner of the building?).

The interpretation of the measured data leads to the conclusion that there are parasitic direct current and alternating current fields (stray currents) corresponding to corrosion category 4 according to TP 124 or ČSN 03 8372 in the area of interest (the current densities J_p at the measuring stations usually exceed the value of 0.1 mA/m^2, both DC and AC modes). The results of the measurements are not in conflict with the Government Regulation on Health Protection against Non-Ionizing Radiation No. 291/2015 Coll., i.e. the values do not exceed hygienic limits.

The situation of the examined object is complicated in that the measurements presented here were ordered and carried out only during construction. The new extensions are based on old foundations which, as far as we have accurate information, have not been examined in more detail. The result of the current measurements is therefore the conclusion that the situation should be further monitored and examined in more detail. However, the further procedure depends mainly on the possibilities and requirements of the investor. A geophysical specialist, together with a structural engineer and an electrical engineer, can only recommend further action.

From the point of view of the geophysicist experience we recommend regular measurements of stray currents in periods of three years. Repeated measurements will be carried out at two fixed outdoor observation stations. The measurement will be carried out in accordance with ČSN 03 8365 with an observation duration of 24 hours. The monitoring also includes repeated measurements of specific resistances, mixed potentials and the speed of propagation of seismic waves at test sites in the foundations of the building. From the magnitude of the velocity of seismic wave propagation, it is possible to judge the degree of strength of the foundations and the changes in this property over time. Assessment of corrosion changes in foundation structures by the seismic method can significantly contribute to a better understanding of degradation processes, especially where access to the investigated objects is difficult.

The article presented here leads to the conclusion that it will be prudent for geophysicists who deal with the above-mentioned issues to deal more comprehensively with the effects of parasitic fields (in the range of DC fields as well as alternating fields) and, within their possibilities, to participate more actively in the creation of Eurocodes in the field of corrosion caused by electric currents.

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