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RESEARCH ARTICLE

Safety of electromagnetic factors for the workplace equipped with personal computers in residential premises

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Abstract

Objectives. The aim of this paper is to analyze the electromagnetic safety of 50Hz industrial frequency electrical networks in residential buildings when using workplaces equipped with personal computers (PCs), as well as to develop recommendations on reducing the impact of levels of industrial frequency electromagnetic fields on human health in residential premises.

Methods. Electromagnetic fields in residential premises with the single-phase TN mode industrial frequency power supply system regulated by the Rules of Electrical Installations Design were measured and calculated in accordance with Russian and international legislative documents.

Results. It was established that electromagnetic fields induced by TN networks in workplaces equipped with PCs might increase significantly and even exceed the maximum permissible level of 25 V/m and 0.25 μ T recommended by Sanitary and Epidemiological Standards. Residential buildings are not subject to the requirements of the Energy Supervision services; therefore, any unprofessional modification of electrical networks in residential premises, including the use of unapproved extension cords, may result in sparking, high-frequency harmonics, and, in turn, conditions which impact human health, as well as electric injuries, fires, and gas explosions.

Conclusions. It has been shown that IT (TT) mode symmetrical two-phase electrical networks may function efficiently for decades without accidents and effects of industrial frequency electromagnetic field on humans, as they are used in medical institutions, defense enterprises, and state institutions. Thus, legislative transition to installing IT (TT) systems in residential buildings, replacement of existing TN power supply systems with IT (TT) system, and legislative strengthening of requirements for household protection and commutation devices, may also be required to reduce man-made disaster risks in residential buildings.

Keywords: residential premises, remote workplace, incompatible standards, dangers of the single-phase electrical network, symmetric network efficiency, ungrounded network efficiency, recommended conditions, self-monitoring

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НАУЧНАЯ СТАТЬЯ

Безопасность электромагнитных факторов на компьютерных рабочих местах в жилых помещениях

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Резюме

Цель. Проанализировать электромагнитную безопасность электрических сетей промышленной частоты (ПЧ) 50 Гц в жилых домах при длительной работе на рабочих местах (РМ) с персональными компьютерами (ПК). Выработать рекомендации по уменьшению воздействия уровней электромагнитных полей (ЭМП) ПЧ на здоровье людей в жилых помещениях.

Методы. В соответствии с российскими и международными нормативными документами проведены измерения и расчеты электромагнитных полей в жилых помещениях, где применяется однофазная система электроснабжения типа TN ПЧ, регламентированная правилами эксплуатации электроустановок.

Результаты. Выявлено, что на РМ с ПК электромагнитные поля, индуцируемые сетями типа TN, существенно возрастают, превышая предельно допустимые уровни: 25 В/м и 0.25 мкТл, рекомендуемые санитарно-эпидемиологическими требованиями. На жилые здания требования служб Энергонадзора не распространяются, поэтому любые непрофессиональные переделки электрических сетей в квартирах и использование несертифицированных удлинителей приводят к искрообразованию, появлению высокочастотных гармоник и, в свою очередь, к дискомфортным условиям, влияющим на здоровье, а также к электропоражениям, пожарам и взрывам газа.

Выводы. Показано, что двухфазные симметричные электрические сети системы IT (ТТ) эффективно функционируют без аварий и воздействия ЭМП ПЧ на людей десятки лет и используются в медицинских, оборонных предприятиях и госучреждениях. С целью уменьшения техногенных катастроф в жилых домах необходимо законодательно перейти на систему IT (ТТ) в жилых домах, заменить существующие системы электроснабжения TN на систему IT (ТТ) и, кроме того, законодательно повысить требования к бытовым устройствам защиты и коммутации.

Ключевые слова: жилое помещение, дистанционная работа, несовместимые нормы, опасности однофазной электросети, эффективность симметричной сети, рекомендуемые условия, самоконтроль

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INTRODUCTION

In practice, even one workplace equipped with PC (WP PC) (sometimes more than 8 hours and during night-time) in residential premise may give rise to problems threatening the life and health of employees (students), as well as other residents. Some households have three or more WP PCs. In addition to the negative stress impact of domestic and family worries, many other cases of extreme fatigue, tiredness, and decreased performance at the end of the working day have been identified in results of private surveys and remote employee complaints, when compared with using WP PCs located in offices.

According to Order No. 33n of January 24, 2014 of the Ministry of Labor and Social Protection of the Russian Federation¹, a special assessment of working conditions in respect to WP PCs was nearly canceled. The new version of the Sanitary and Epidemiological Norms (SanPiN)² approved by the Federal Service for Surveillance on Consumer Rights Protection and Human Well-being (Rospotrebnadzor) entered into force. This was without any argumentation in terms of sanitary impacts, or discussions with experts on Internet. This also excluded Swedish electromagnetic compatibility (EMC) requirements for WP PCs (SanPiN 2.2.4.3359-16³, paragraph 7.2.7, Table 1), while canceling SanPiN itself.

Remote WP PCs are located usually in residential premises often unadapted for this purpose (power supply, Internet connection, office equipment, and communication). While the employer is responsible for safety in office WP PCs, ensuring responsibility for the fire, electrical, and electromagnetic safety of the remote workplace does not fall under supervision of the Russian Ministry of Emergency Situations, Energy, and Sanitation Departments.

All departmental documents related to ensuring safe conditions in housing and communal services (HCS)

refer to paragraph 1 of Article 161 of the Housing Code of the Russian Federation of 03.04.2018 № 59-FZ⁴. This states that “the management of an apartment building should ensure the favorable and safe living conditions for citizens”. It also proposes a General Declaration. Thus, users themselves are now responsible for monitoring living conditions in premises and safety of WP PCs, in order to preserve their health as well as the health of other residents.

Remaining indoors for too long may become uncomfortable and dangerous in conditions of weakened geomagnetic field (GMF) and distorted geoelectric field (GEF), as well as in conditions of increased man-made electromagnetic fields (EMF). Residents today may not even realize the reduced natural EMF and increased man-made EMF in their homes, WP PCs, bedrooms, and kitchens. The Ministry of Emergency Situations, health and sanitary information, and mass media cannot encourage residents to monitor EMF conditions in their premises independently, despite the simplicity of such monitoring comparable with the use of a smartphone [1–7].

After monitoring complaints from house residents for several years concerning dangerous and uncomfortable living conditions has revealed that up to 60% of all cases are caused by electrical networks with TN earth system⁵ with solidly grounded neutral (French: Terre – Neuter) in accordance with the Rules of Electrical Installations Design (PUE)⁶ for residential premises (PUE, paragraph 7.1.13) and public buildings (PUE, paragraph 7.2.9) [1]. Left over many years, unattended household TN electrical networks may result occasionally in sparking and short circuits (SC). This may result in multiple accidents, such as explosions, fires, and electrical injuries causing destruction of buildings and loss of life.

In contrast to international standards on electrical safety, Russian electrical networks are equipped with circuit breakers (CBs) and residual current devices (RCDs) with reduced reliability requirements. This exacerbates the risks of explosion, fire, and electrical hazards in buildings with TN mode single-phase power supply. Two-phase symmetrical IT (TT) networks⁷ with safety criteria much higher than those of TN networks should be used in residential and public buildings

¹ Order of the Ministry of Labor and Social Protection of the Russian Federation No. 33n of January 24, 2014 on the endorsement of the Method of special assessment of working conditions, Classifier of adverse and/or hazardous production factors, form of report of the carried out special assessment of working conditions and its filling instruction. Amended on April 27, 2020 (in Russ.).

² SanPiN 1.2.3685-21 Hygienic Standards and Requirements for Ensuring Safety and/or Harmlessness of Environmental Factors for Humans. Approved by the Order No. 2 of 28.01.2021 of the Chief State Sanitary Physician of the Russian Federation (in Russ.).

³ SanPiN 2.2.4.3359-16 Sanitary and Epidemiological requirements for physical factors in the workplace. Approved by the Order No. 81 of 21.06.2016 of the Chief State Sanitary Physician of the Russian Federation (in Russ.).

⁴ Federal Law on Amendments to Housing Code of Russian Federation No. 59-FZ, dated April 3, 2018 (in Russ.).

⁵ Electrical network with solidly grounded neutral in accordance with PUE, paragraph 1.7.3 (in Russ.).

⁶ Rules of Electrical Installations Design (PUE). Approved by the Order No. 204 of the Ministry of Energy of the Russian Federation on July 8, 2002 (in Russ.).

⁷ Electrical network with isolated neutral in accordance with PUE, paragraph 1.7.3 (in Russ.).

with no actual network supervision (before failure or emergency).

Forty-four cases of domestic gas explosions in Russian residential buildings in 2017–2018 have resulted in victims and casualties. The explosions in Izhevsk (09.11.2017) and Magnitogorsk (31.12.2018) were the most devastating. In the latter case, repair costs are estimated at over RUR 5 bn. The recent explosions (in Noginsk on September 8, 2021 and Yeletz on August 11, 2021) resulted in more than ten dead and about hundred injured people. The total damage to the Budget and expenditures of the affected population amounts to billions of rubles.

Even S.K. Shoigu, the Minister of Emergency Situations, has stated that every third fire and explosion in the HCS sector is caused by the TN electrical network. Every year up to 30000 people die due to electric shock in Russia. The level of electrical injury in Russian households is much greater than that in the USA and Japan⁸.

TN networks with an industrial frequency (IF) of 50 Hz, network extension cords, and appliance and adapter cords may induce a wide spectrum of EMF harmonics with amplitude exceeding maximum permissible level (MPL) of 25 V/m for WP PCs, according to SanPiN 2.2.4.3359-16, in living spaces (WP PC, bedroom, and kitchen) at a distance of over 0.5 m, thus creating uncomfortable living and working conditions [1].

INCOMPATIBILITY BETWEEN SANPIN CONCERNING IF EMF FOR RESIDENTIAL PREMISES AND WP PC CONDITIONS

The sanitary and hygiene standards and rules for IF EMF (EF and MF are electric and magnetic fields, respectively), and MPL established by SanPiN 2.1.2.2645⁹ for living conditions in residential buildings and premises do not meet MPL requirements for WP PCs as specified in the latest version of SanPiN 2.2.4.3359-16 (paragraph 7.2.7).

The MPL of significant EMF factors for WP PCs as specified in SanPiN 2.2.4.3359-16 is compared in Table 1 with the IF EMF (EF and MF) MPL as

specified in SanPiN 2.1.2.2645-10. For many years, designers and power engineers have been using this reference MPL (500 V/m and 5 μ T). The aim is to avoid using safe symmetrical two-phase IT mode power supply system (PUE, Fig. 1.7.4) in residential and public buildings instead of TN networks which are potentially dangerous to households. However, the use of an IT system may reduce the risk of emergencies and maintain suitable conditions for IF EMF factors [1].

This paper proposes advisable practically achievable criteria of safe conditions for EMF factors in their combined effect on WP PCs, in order to reduce the risk of emergencies, while preserving the health of remote WP PC users. This also prevents the uncontrollable effects of uncomfortable IF EMF factors along with other significant EMF factors. The recommended criteria were developed on the basis of experimental data and are compatible with the EMF values specified in SanPiN 2.2.4.3359-16 (Table 1), the criteria of Standard der Baubiologischen Messtechnik (SBM-2015) (Germany)¹⁰ for sleeping areas, and the World Health Organization (WHO) principles [1, 2].

The primary aim of the paper is to establish the following: the causes of TN network operational hazards in residential premises; the safety and efficiency of IT networks; and the need for self-monitoring of recommended IF EMF criteria for WP PCs.

Uncomfortable EMF conditions in premises today depend not only on the construction quality and external environment, but also on the residents and their qualifications, as well as self-monitoring system and the capability to normalize these conditions. Equipping WP PC should be accompanied with continuous monitoring of IF EMF and other factors (Table 1). Periodic monitoring should be carried out when WP PCs are operating, as well as changes to conditions in the premises. Individual study recorders (ISR) used as control devices are used for nondestructive testing and are not subject to state verification (Art. 1.23, Federal Law No 102-FZ¹¹ of 26.06.2008, as amended on 23.06.2014).

⁸ About active harmonic filters for “weasels” and the rules for choosing filter compensating devices. URL: <https://www.mircond.com/blog/ob-aktivnykh-filtrakh-garmonik/>. Accessed April 20, 2020 (in Russ.).

⁹ SanPiN 2.1.2.2645-10 Sanitary and Epidemiological Requirements for Living Conditions in Residential Buildings and Premises. Approved by the Order No.64 of 10.06.2010 of the Chief State Sanitary Physician of the Russian Federation (in Russ.).

¹⁰ Supplement to the Standard of Building Biology Testing Methods SBM-2015 and the associated Building Biology Evaluation Guidelines for Sleeping Areas. [Acting from 5th Draft 5/2015]. Germany: Institut für Baubiologie + Ökologie IBN; 2015, p. 18.

¹¹ Federal Law No. 102-FZ On Ensuring the Uniformity of Measurements, dated 26.06.2008 (in Russ.).

Table. 1. Comparison of EMF MPL for WP PC and EMF MPL for the residential premise

SanPiN 2.2.4.3359-16 (8 h)		Background MPL	SanPiN 2.1.2.2810-10* (24 h)	MPL
EF intensity	5–2000 Hz	25 V/m	50 ± 2 Hz EF background in the premise	500 V/m
	2–400 kHz	2.5 V/m		
MF intensity	5–2000 Hz	0.25 µT	50 ± 2 Hz MF background in the premise	5(4) µT (A/m)
	2–400 kHz	25 nT		
SHF frequency	300–300000 MHz	10 µW/cm ²	300–300000 MHz	10 µW/cm ²
ESF intensity		15 kV/m	–	15 kV/m
GMF reduction factor, K_g		$K_g \leq 2.0$	–	$K_g \leq 1.5$

Notes:

1. ESF is electrostatic field measured according to paragraph 7.3.7. of SanPiN 2.2.4.3359-16; it specifies the superposition of GEF and ESF in the premise.
2. GMF is geomagnetic field; K_g is GMF reduction factor, according to GOST (State Standard) R 51724–01(08)**.

* SanPiN 2.1.2.2801-10 Amendments and additions No. 1 to SanPiN 2.1.2.2645-10 Sanitary and epidemiological requirements for living conditions in residential buildings and premises (with amendments approved by the Order No. 2403 of the Russian Government dated 31.12.2020) (in Russ.).

** GOST R 51724-2001. Shielded facilities, spaces, installations. Reduced geomagnetic field. Methods of measuring and assessment of field intensity compliance with technical requirements and hygiene standards. Moscow: Standartinform; 2001 (in Russ.).

CAUSES OF UNSUITABLE CONDITIONS FOR REMOTE WP PCS IN RESIDENTIAL PREMISES

Millions of WP PCs located in offices, classrooms, and factories are subject to EMF requirements and standards (Table 1) and these should also be extended to remote users in residential premises. These requirements were first set out in the MPR 1990 standard (Sweden)¹²,

¹² Standard MPR 1990:10 1990-12-31 within MPR II standards developed by the Swedish Board for Technical Accreditation (SWEDAC) as the User's Handbook for Evaluating Visual Display Units. Adopted as European Standard in June 1992 by the Council Directive 90/270/EEC of May 29, 1990.

and have been used worldwide as MPL for WP PCs equipped with electronic tube displays. Since 2000, WP PCs have been equipped with new and safer LCD displays. At the same time, secondary switched power supplies (SMPS), such as adapters, electric appliances, light-emissive device, and etc., distorting IF currents and voltages of 50 Hz in TN network have come into broader use. This induces a parasitic EF and MF spectrum on frequency bands almost equal to the MPR 1990 standard in the premises.

Figure 1 shows typical voltage and current waveform distortions in a three-phase 50 Hz electrical network of a residential building.

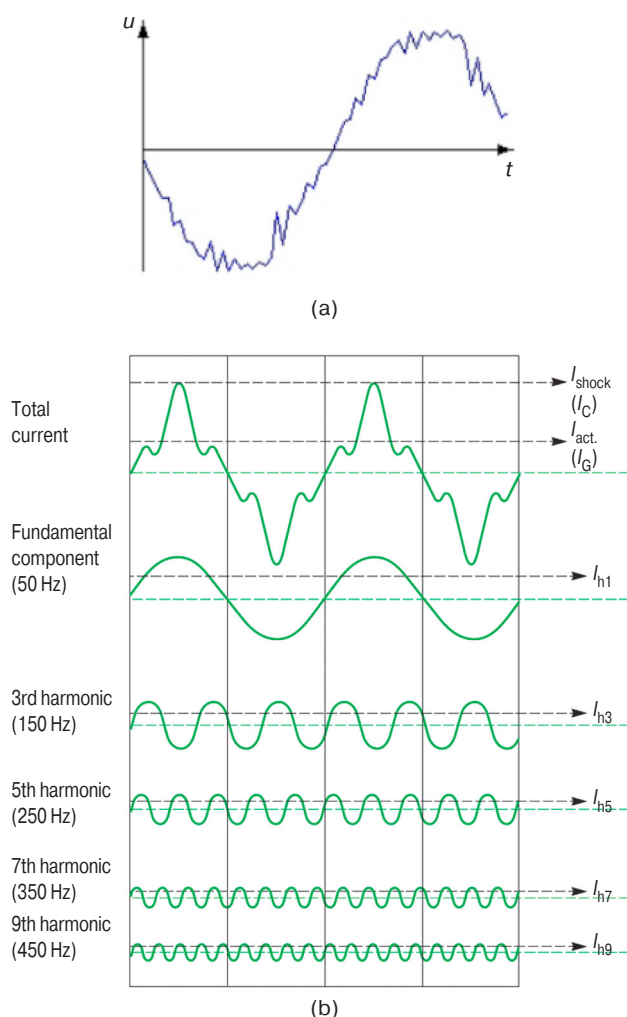


Fig. 1. Typical distortions:
(a) of voltage;

(b) of currents and their harmonics distorting
the current waveform in the three-phase 50 Hz
electrical network of a residential building;
the x-axis shows time while the y-axis corresponds to
the parameter amplitude

Current distortions may be caused mainly by asymmetry of consumer phase loads in the building network and nonlinear current loads in phases. Each current (voltage) harmonic of the TN network phase induces MF (EF) in living spaces and form a wideband spectrum with energy possibly greater than that of the 1st harmonics. The Swedish standard requirements for IF EMF (Table 1) are kept in SanPiN 2.2.4.3359-16 for office WP PCs. In the meantime, they have proven their efficiency in terms of preventing harmful effects on users and fail-safety. Today, the monitoring of these requirements is provided by a large network of devices in Russia.

However, paragraph 7.2.7. of SanPiN 2.2.4.3359-16 (Table 1) concerning EMF norms for WP PCs has been completely removed from the new SanPiN 1.2.3685-21 version. This was done with no argumentation in terms

of sanitary and discussions with experts on Internet, while the SanPiN norms were cancelled themselves. The impact of this initiative on the health of WP PC users located in offices, and especially remote users in residential premises where TN networks induce uncontrolled high IF EMF exceeding MPL for WP PCs, is unpredictable. Today even entrepreneurs and administrative managers (constructors and power engineers) are interested in accident-free conditions and protecting the health of their remote employees. Their business depends on their efficiency, and they are keen to protect the health of children, pregnant women, students, and etc.

The SanPiN 2.1.2.2645-10 (Table 1) requirements and their control methods do not reflect the sanitary hazard of IF EMF in natural conditions of residential premises (as well as in the equipped WPPC, respectively) for the following reasons:

1. Today, up to 80% of the parasitic energy of the IF EF and MF harmonic induction spectrum which actually affects individuals in residential premises (Fig. 1) is not controlled. According to the “thermal concept” criteria established in Russia and applied to standards in other countries, e.g., to Directive 2013/35/EU¹³ of 26 June, 2013, MPL induction norms should be reduced in the low frequency range in proportion to the increasing frequency (minus 6 dB per octave). SanPiN sets flat MPL norms, irrespective of frequency.

The flat wideband MPL norms for exposure to EMF of band frequencies ranging from 10 kHz to 300GHz as established in the USSR in the 1960s (also given in the new version of SanPiN 1.2.3685-21) were developed secretly. This prevents the possibility of determining the narrowband frequencies of codes, heterodyne radiations, transceivers, and antennas. Incompatibility between foreign standards for the specific absorption rate (SAR) and MPL set in SanPiN may require additional costs for controlling imported facilities. This approach prevents the harmonization of Russian sanitation and hygiene standards with those of the developed Western countries.

Network harmonics may result in additional heating of power transformer windings. This also decreases their rated power and residual life. Industrial standards for the harmonic levels in

¹³ Directive 2013/35/EU of the European Parliament and of the Council of 26 June 2013 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields) (20th individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC) and repealing Directive 2004/40/EC

industrial (but not residential) building networks have been already standardized to the 40th harmonic (up to 2000 Hz) in GOST 32144-2013¹⁴ (for voltage) and GOST IEC 61000-3-2-2017¹⁵ (for current). Thus, damage to power equipment and unscheduled power outages may occur more often in HCS.

2. The entire TN network including socket and lighting circuits, network extension cords, inter alia are sources of IF EF and MF induction in the premises (also in WP PCs). Plugged in SMPS extensions and cord (~220 V, 50 Hz), as well as two-wire networks even without load are the most intensive EF sources close to the user. Due to specificity of SMPS (adapters), their cords may induce the EF frequency spectrum of 100–500(2000) Hz with intensity $E \geq 25$ V/m at a distance up to 0.5 m, where first EF harmonic is 100 Hz rather than 50 Hz [3].
3. Exposure energy of EP and MF harmonics may increase in premises due to the broad introduction of wireless power transfer (WPT) sources for charging mobile and portable devices, household appliances, and electric cars. In the USA, more than 30% of cell phones are now charged from WPT sources.
4. In SanPiN 2.1.2.2810-10 (Table 1), MPLs for IF EMF are given on the assumption that EF and MF induction may occur in residential premises from the single-phase network only. However, some locations including WP PCs may be in the region of rotating IF EMF (REMF) (REF and RMF for components) induced via a three-phase cable layout connecting kitchen cookers, transformers, engineering equipment, distribution panels, and elevators.

The effect of RMF on living organisms may be more dangerous when compared with the effect of MF from a single-phase circuit. Right-hand RMF is less destructive than left-hand. Exposure to lefthand RMF is more dangerous even at low levels. Today, there are no standards for REMF directions. Premises intended for remote work should be inspected for the absence of RMF and REF from external and internal sources [8–10].

The results of measuring zones of spatial distribution of 50 Hz IF EMF levels (MF, EF, and their ellipticity)

in four directions, according to the method specified in SanPiN 2.2.4.3359-16, paragraph 7.3.4, induced by five types of cast resin dry type transformers (CRT) ranging from 1000 kVA to 2500 kVA used in urban transformer substations and facilities are given in [11].

About forty transformer substations built-in and attached to building in Moscow, Moscow region, and Samara are equipped with shields (thin-walled steel sheets with a grid between them). They convert elliptical IF RMF of the source to the quasi-linear component of IF MF (less dangerous), according to the method described in [11].

5. Today, foreign environmental organizations recommend (oblige) builders to comply with rigid SBM-2015 standard (8th edition) for advisable 50 Hz IF background in residential premises. This should be no more than 5 V/m and 0.1 μ T, motivated by WHO warning provisions for residents' exposure to household EMF and other harmful factors. The SBM-2015 standard of building biology methods is used as a guide for professionals and independent testing of residential buildings worldwide, including Europe, Israel, USA, Canada, Australia, and New Zealand [12].
6. In the European Union, the transition to standards for IF MF ranging from 0.2 to 0.4 μ T is considered as a promising target for coming years. The decisions at the WHO level are expected to be made in 2022–2024 [13].

CAUSES OF DANGEROUS CONDITIONS IN RESIDENTIAL PREMISES DUE TO TN POWER SUPPLY SYSTEMS

The mass media often cite TN electrical networks among the causes and conditions of accidents occurring in residential and public buildings, resulting in injury and death. According to the degree of potential danger to the quality of life (QOL) and health of the residents, costs of treating victims, as well as damage to work results along with costs of future restoration and repair, these accidents should be classified as extremely dangerous for their resulting frequently in catastrophic damage.

Two-wire TN-C network¹⁶, among other TN modes, may most frequently cause domestic gas explosions, fires, electrical injuries, and parasitic inductions of 50 Hz IF fields in premises. These networks may be found in building walls towards outlets and light sources (due to mistakes

¹⁶ TN electrical network with combined earthing (PE) and neutral (N) wires.

¹⁴ GOST 32144-2013. Electric energy. Electromagnetic compatibility of technical equipment. Power quality limits in the public power supply systems. Moscow: Standartinform; 2014 (in Russ.).

¹⁵ GOST IEC 61000-3-2-2017. Electromagnetic compatibility (EMC). Part 3–2. Limits. Limits for harmonic current emissions (equipment input current no more 16 A per phase). Moscow: Standartinform; 2020 (in Russ.).

of constructors) as well as in cases of contact failures in the third PE¹⁷ wire and non-standard extension cords. The two-wire network may be detected by the increased EF induction.

A short circuit in a TN-C network can result in fire. When a PEN¹⁸ neutral wire is broken or burnt, the voltage at the L (phase wire) terminals may increase up to 0.4 kV. This voltage is dangerous to people and may appear on all metal parts connected to the PEN wire. According to PUE, paragraph 7.1.78, plugged in and unprotected domestic appliances, adapters, and light sources may be burnt. In Russia, using the TN-C networks and two-wire extension cords are currently prohibited by fire authorities.

Despite the use of upgraded TN-S¹⁹ and TN-C-S²⁰ power supply systems in residential buildings, according to PUE, paragraph 7.1.13, gas explosions, fires, and electric injuries may also occur from time to time in recently constructed buildings. In Russia, about 30–50% of annual household gas explosions are caused by sparking in TN electrical network. This usually happens when commutating light switches, socket contacts, electrical appliances, inter alia. Spark intensity may increase due to the additional discharge energy of the distributed capacitance $C_D = 110...130$ pF/m from the “earth” wire. It is therefore not recommended to use TN networks in areas of possible concentrations of dust and air explosive mixtures. Sparking may be dangerous for electronic devices in the event of earth fault (contact loss) and other factors.

Today, protection against electrical hazards and short circuits in TN-S and TN-C-S building networks depends on the CB and RCD response speed. Fires and electrical hazards may often occur due to the low contact reliability of electromechanical devices and long response time (up to 5 seconds, according to PUE, paragraph 1.7.79) in residential and public building networks. According to the expert opinion on the cause of the fire in the Zimnyaya Vishnya shopping mall: “The fire started in the LED light fixture which was inundated by melt water from

the roof. The circuit breakers intended for switching off the lighting device and then the power supply failed to actuate²¹.”

Electric shock and commutation sparking occurring in TN building networks is always added to the discharge energy of the distributed capacity C_D . This causes degradation (erosion) of contacts. In TN system, the presence of electromechanical CB and RCD does not mean full protection against short circuits and electrical hazards. Protection devices with a cut-off time two orders of magnitude less than that established in PUE [1, 2] are required.

CAUSES OF UNSUITABLE CONDITIONS FOR REMOTE WP PCS DUE TO IF EMF

Complaints from domestic residents with regard to unsuitable living conditions are often due to the 50 Hz IF EF and MF induction. These frequently do not exceed the MPL established by SanPiN 2.1.2.2810-10 (Table 1). Voltages in TN electrical networks running in walls, ceiling, and floor may actuate steel rebars and wall grids (not earthed) and induce parasitic (secondary) EF with intensity up to 25 V/m (MPL for WP PCs) in premises at 0.4–1.0 m from walls. Network extension cords running under the user’s feet, especially two-cable ones (used at more than 50% of WP PCs in Russia), appliance and adapter cords, and table (wall) lamps may induce EF in the surrounding space. This excites secondary EF in metal objects located close to the user, such as tabletop, chair, armchair, support, spring mattress, inter alia.

In the case of locating WP PCs, conditions may become unsuitable even when all the cords of IT devices and adapters are merely plugged into the sockets and extension cords of the TN power supply (~220V). IF EMF intensity at a distance of 0.1 m from cords and three-wire extensions may reach 100–125 V/m. This is 4–5 times more than MPL for WP PCs (25 V/m) established by SanPiN 2.2.4.3359-16 (Table 1) [1, 2].

The need to multiply the TN network (plugging appliance cords, adapters, and etc. in) by means of extension cords, as well as increasing the number of current commutations when equipping and operating WP PCs in residential premises, may increase the risk of explosion, fire, electrical sparking, and unsuitable conditions, which are monitored and protected by nobody. In TN network, dangerous conditions often arise when the contacts of the working and protective earth wires are broken or lost even before entering the premises, apartment, distribution board, inter alia.

¹⁷ PE is protective earthing. It is used for protection against electric shock and emergency shutdown of differential protection and circuit breakers in case of insulation failure in electrical appliances with earthed enclosure.

¹⁸ Protective earthed neutral (PEN) conductor is a single conductor combining the function of the neutral and protective earth conductor.

¹⁹ TN electrical network with earthing (PE) and neutral (N) wires.

²⁰ TN electrical network with combined earthing (PE) and neutral (N) wires at the network beginning and separate earthing (PE) and neutral (N) wires further on.

²¹ The Kommersant newspaper of August 24, 2018 (in Russ.).

There have been a number of instances, when a baby's bed located close to and exposed to EF voltage of $\sim(80\text{--}100)$ V/m emitted by device cords (heater, ionizer, baby monitor, etc.) has been relocated to another place, thus normalizing EF conditions to less than 10 V/m, resulting in the disappearance of chronic diseases [2].

SAFE POWER SUPPLY SYSTEMS REQUIRED FOR REMOTE WP PCS

There is no statistical data regarding accidents and excesses of IF EF and MF values in healthcare facilities, defense enterprises, and banks using potentially safe two-phase symmetrical IT (TT) networks, manufactured pursuant to GOST R 50571.28-2006 (IEC 60364-7-710: 2002)²² (PUE, Fig. 1.7.4).

The results of inspections and tests performed in buildings in accordance with RD 153-34.0-15.501-00²³ and RD 153-34.0-15.502-2002²⁴ show that the IT electrical network efficiency is higher than that of the TN, in terms of the following values:

- Explosion and fire risks, up to 5 times;
- Electrical safety, more than 10 times;
- Electromagnetic safety, at least 10 times;
- Pulse (lightning) resistance, by 1.5–3 times (civil defense);
- Energy saving (current drain reduction), up to 5%;
- Resource conservation including network isolation and commutation device contacts as well as reduction in the electro corrosion rate of building engineering systems, by 2–3 times, etc.

Contact with any wire of the IT network is safe, and secondary inductions from ungrounded objects do not occur. IF EF inductions from network extensions decrease. Conventional CB and RCD protection devices, as well as electromagnetic shielding would be more effective for these networks. When commutating current loads and short circuits, the spark energy is

several times lower due to the absence of capacity discharge C_D . This energy may be compensated by multidirectional bias currents from each wire of the network. The cases of domestic gas explosions are unknown yet [1–3].

In the case of a single ground fault in one of the IT network conductors, even though the circuit breakers have not tripped, the IT network may be converted provisionally into TN-C network until the fault is eliminated. In the case of a ground fault in the second conductor, the emergency network should be switched off. Voltage to earth from each IT network wire is about 110 V. The EF intensity is 1–2 V/m, while the MF one is about 10 nT at 0.1 m from the wires [2].

Today, the service entrance for the three-phase TN network ($\sim 220\text{V}$) in an apartment or detached house may have been equipped by certain enterprising people with an isolation transformer (PUE, paragraph 1.7.85) up to 15.0 kW. This transmits an already potentially safe electrical IT network or TT network earthed via a middle point (PUE, Fig. 1.7.5) to WP PCs in residential premises through the same wires. In order to protect a detached house from EF and MF parasitic inductions, as well as from parasitic interferences in the electrical network which may occur during thunderstorm, short-circuit, and wire breakage, an isolation transformer with separate windings (or with the earthed shield) and overvoltage suppressors may be installed on the property line [2].

In order to protect remote WP PCs from IF EF of TN network (~ 220 V), neutralizers may be used for decoupling ~ 220 V from ground (earth), suppressing EF in the range from 5 Hz to 400 kHz, with a noise level up to 20 dB, such as Cyclone 650 with 4 sockets (produced by the Cyclone-Test²⁵).

RECOMMENDED VALUES AND CRITERIA OF EMF CONDITIONS FOR REMOTE WP PCS

Table 2 indicates the values for EMF factors recommended for different degrees of harm and/or danger criteria for WP PC, where 1 is comfortable, 2 is allowable, 3 is safe, and 4 is unacceptable. These values are harmonized with SBM-2015 standard criteria and WHO principles.

EMF factor levels for WP PCs may be monitored pursuant to the methods described in paragraph 7.3.7 and Appendix 11 of SanPiN 2.2.4.3359-16, until a time when new recommended methods are proposed. IF EMF criteria 1 and 2 (comfortable and acceptable conditions) in residential premises (in WP PC, also)

²² GOST R 50571.28-2006 (IEC 60364-7-710: 2002). Electrical installations of buildings. Part 7-710: Requirements for special installations or locations. Medical locations. Moscow: Standartinform; 2007 (in Russ.).

²³ RD 153-34.0-15.501-00 Guidelines for monitoring and analyzing the quality of electric energy in general-purpose power supply systems. Part 1. Electrical energy quality control (approved by Ministry of Energy of the Russian Federation on December 27, 2000) (in Russ.).

²⁴ RD 153-34.0-15.502-2002 Methodological guidelines for control and analysis of power quality in power supply systems for general purposes. Part 2. Analysis of power quality (approved by Rostekhnadzor on July 15, 2002) (in Russ.).

²⁵ www.ciklon.ru

are reliably fulfilled, provided that an IT network (or TT network) is used and there is no induction or radiation from external sources which exceed the criteria, specified in Table 2.

JUSTIFICATION FOR EMF RECOMMENDED CRITERIA (TABLE 2) FOR WP PCS

An example of parasitic EF (23 V/m) induced by a cord plugged into the network adapter (~ 220 V) at ~ 0.5 m (wooden ruler) close to IF EF MPL for WP PC (Table 1) is shown in Fig. 2. However, the EMF MPL value is currently measured at 0.1 m from the device (SMPS for WP PC of ≤ 25 V/m), according to SanPiN 2.1.2.1002-003²⁶, paragraph 6.4.3.1.



Fig. 2. Induction of EF (23 V/m) at ~ 0.5 m from cord plugged into a network adapter (~ 220 V)

An example of a household WP PC is shown in Fig. 3 [14]. Clearly the PC power cords and LCD display and laptop cables are hanging down from the metal tabletop and are plugged into extension outlet sockets. When a TN network is used, the EF and MF secondary induction (ranging from 5 Hz to 2 kHz) from the tabletop and cords near the user's knees may be up to 80 V/m and $0.6 \mu\text{T}$ instead of MPL amounting to 25 V/m and $0.25 \mu\text{T}$.

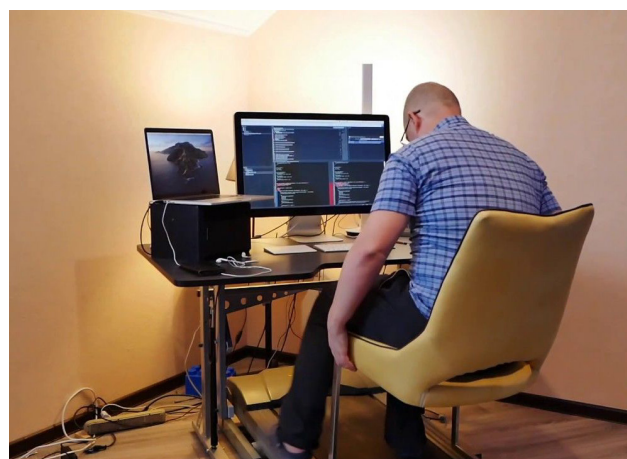


Fig. 3. Household WP PC [14]

Other factors of discomfort (Fig. 3) may be: IF MF, EF, and RMF induction from power cables behind the wall; inductions of the opposite directions of GEF or ESF vectors of the armchair, foot support and floor laminate; reduction of GMF due to wall metal structures; SHF radiation from nearby devices, such as Wi-Fi devices, laptop board, and cell phones (especially, using GSM standard). When an IT network is used, IF EF and MF values would *automatically* meet the conditions specified in Table 2.

Remote WP PCs should comply with EMF values and criteria (Table 2) rather than EMF MPL established by SanPiN (Table 1) for living conditions. The reasons are as follows:

1. Hygiene and sanitary documents for residential premises as developed by the Research Institute of Occupational Medicine contain MPL values for single-component exposures to EMF factors only (Table 1). In addition, these MPL values (500 V/m and $5 \mu\text{T}$) conflict with EMF norms as established by SanPiN 2.2.4.3359-16 for office WP PCs (25 V/m and $0.25 \mu\text{T}$).
2. WP PC users today may be exposed to the range of EMF factors, all of which can have a devastating impact on health. Based on publications by medical and other experts, the following body systems may be susceptible to each EMF factor exposure (Table 1): nervous system; cardiovascular system; endocrine system; immune system; digestive system; and the reproductive system [10]. When WP PC is exposed to the range of EMF factors, the intensity of each factor should be reduced to protect against the devastating health impact on users.
3. The recommended criteria for factors 4 (Table 2) are more severe than EMF MPL (Table 1). Here, the following aspects have been considered:

²⁶ SanPiN 2.1.2.1002-00. 2.1.2. Design, construction and operation of residential buildings, public utilities companies, education, culture, recreation, and sport institutions. Sanitary and epidemiological requirements for residential buildings and premises. Sanitary and epidemiological rules and regulations (Approved by the Chief State Sanitary Physician of the Russian Federation, December 15, 2000, edited August 21, 2007) (in Russ.).

Table 2. Recommended values and criteria of EMF conditions for remote WP PCs

Values		UM	Criteria			
			1	2	3	4
EF intensity, line-to-earth	5–2000 Hz	V/m	<1	1–5	5–25	>25
	2–400 kHz	V/m	<0.1	0.1–0.25	0.25–2.5	>2.5
EF intensity, ungrounded	5–2000 Hz	V/m	<0.3	0.3–1.5	1.5–10	>10
	2–400 kHz	V/m	<0.02	0.02–0.1	0.1–0.5	>0.5
MF intensity	5–2000 Hz	nT	<2.5	2.5–7.5	7.5–25	>50
	2–400 kHz	nT	<0.25	0.25–0.75	0.75–25	>5
SHF energy flux density	300–300000 MHz	$\mu\text{W}/\text{m}^2$ $\mu\text{W}/\text{cm}^2$	<1.0 <10 ⁻⁴	1–100 10 ⁻⁴ –10 ⁻²	100–1000 10 ⁻² –0.1	>1000 >0.1
ESF intensity	E	kV/m	<0.1	0.1–0.5	0.5–3.0	>+3.0
ESF leakage time in humidity conditions	t_l (30–60)%	s	<2.0	2.0–6.0	6.0–15	>15
GMF reduction factor, K_r	$K_r = H_{OS}/H_{IN}$	Ratio	<1.1	1.1–1.3	1.3–1.5	>1.5

Notes:

1. ESF (E) intensity is measured under simulated conditions for WP PCs and leakage time (t_l) of induced ESP charge on the floor and WP PC dielectric materials (including electrostatic charging of the user body [clothes and shoes] in motion), according to GOST 31610.32-2-2016 / IEC 60079-32-2:2015*.
2. Safety analysis, as well as the monitoring and justification of the recommended criteria for SHF, ESF, and GMF factors for remote WP PCs in residential premises will be given in subsequent papers.
3. H_{OS} is open space GMF intensity; H_{IN} is indoor GMP intensity.

* GOST 31610.32-2-2016/IEC 60079-32-2:2015. Explosive atmospheres. Part 32-2. Electrostatics hazards. Tests. Moscow: Standartinform; 2017 (in Russ.).

use of safe IT (TT) network in buildings and premises; exposure to the reduced and distorted GMF factors in premises practical achievability of the criteria indicated in Table 2; MPL reduction of other physical factors in the event of 24 hours, instead of 8 hours, in the office.

CONCLUSIONS

1. Based on the above results, the following priority activities should be implemented in residential buildings and premises as legislation:
 - Replacement of TN power supply system with IT (TT);
 - Use of a more reliable commutation and protection systems;
 - Implementation of a system for monitoring physical factor conditions by residents and users of household WP PCs who use modern mobile devices.

2. The following requirements should be conveyed to the Government of the Russian Federation, regional authorities, population, investors, constructors, and power engineers: use of ungrounded IT power supply system in designing new residential and public buildings, rebuilding, and overhauling; recommendation for the safe and comfortable EMF factor conditions as shown in Table 2 for sleeping accommodation and WP PC.
3. It is recommended that the Head of Rospotrebnadzor perform the following activities:
 - To include the canceled SanPiN 2.2.4.3359-16, Table 7.12, defining the EMF MPL values for WP PCs (preferably, as indicated in Table 1 in the paper) in new version of SanPiN 1.2.3685-21.
 - To promote the self-monitoring of safety conditions for remote WP PCs.

Authors' contribution

Yu.G. Ryabov—development of the research concept; conducting research, in particular, analysis of standards for the impact of EMF in Russian and foreign regulatory documents and analysis of dangerous conditions for RM PCs in existing electrical networks of residential buildings; development of recommendations for reducing EMF and formulation of required EMF indicators for RM PC in residential buildings; writing the text of the article.

N.M. Legkiy—design of key goals and objectives; conducting research, in particular, analysis of means of protection against electric shocks and short circuits in electrical networks; analysis of safe power supply systems required for RM PCs in residential buildings; analysis of

literature data; formulation of required EMF indicators for RM PCs in residential buildings; writing and editing the text of the article.

G.V. Lomaev—design of key goals and objectives; conducting research, in particular, analysis of the Russian regulatory documents for EMF and interpretation of the data obtained; development of criteria for assessing the safety of electrical networks in residential buildings; analysis of literature data; formulation of required EMF indicators for RM PC in residential buildings; critical revision of the article with the introduction of valuable comments.

All authors—interpreting the study results, formulating the conclusions, and final approval of the version to be published.

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