Chemical Technology, Control and Management

Volume 2021 | Issue 2 Article 7

5-17-2021

ERRORS OF UNIVERSAL CONTACTLESS CONVERTERS OF MONITORING AND CONTROL SYSTEMS FROM EXTERNAL MAGNETIC FIELDS

A.M Plakhtiev
Tashkent institute of irrigation and agricultural mechanization engineers Address: 39, Qori Niyaziy str., 100000, Tashkent city, Republic of Uzbekistan E-mail: 1a.plakhtiev@mail.ru, phone: + 998-90-943-59-25;, a.plakhtiev@mail.ru

Gayratjon Gaziev
Triple Point Engineering LLC Address: 1, Beshagach str., 100066, Tashkent city, Republic of Uzbekistan E-mail: gazievgayrat@gmail.com, phone: + 998-95-513-43-33., gazievgayrat@mail.ru

Yahyojon Meliboyev
Tashkent institute of irrigation and agricultural mechanization engineers Address: 39, Qori Niyaziy str., 100000, Tashkent city, Republic of Uzbekistan, meliboyevyahyojon@gmail.com

Odil Doniyorov
Tashkent institute of irrigation and agricultural mechanization engineers Address: 39, Qori Niyaziy str., 100000, Tashkent city, Republic of Uzbekistan, odilbekdoniyorov@mail.ru

Recommended Citation
Plakhtiev, A.M; Gaziev, Gayratjon; Meliboyev, Yahyojon; and Doniyorov, Odil (2021) "ERRORS OF UNIVERSAL CONTACTLESS CONVERTERS OF MONITORING AND CONTROL SYSTEMS FROM EXTERNAL MAGNETIC FIELDS," *Chemical Technology, Control and Management*: Vol. 2021 : Iss. 2 , Article 7.
DOI: https://doi.org/10.51346/tstu-02.21.1-77-0007
Available at: https://uzjournals.edu.uz/ijctcm/vol2021/iss2/7

ISSN 1815-4840, E-ISSN 2181-1105
Himičeskaâ tehnologiâ. Kontrol' i upravlenie
CHEMICAL TECHNOLOGY. CONTROL AND MANAGEMENT
2021, №2 (98) pp.47-55. https://doi.org/10.51346/tstu-02.21.1-77-0007
International scientific and technical journal
journal homepage: https://uzjournals.edu.uz/ijctcm/
Since 2005

UDC 621.317.714

ERRORS OF UNIVERSAL CONTACTLESS CONVERTERS OF MONITORING AND CONTROL SYSTEMS FROM EXTERNAL MAGNETIC FIELDS

A.M.Plakhtiev[1], G.A.Gaziev[2] , Y.A.Meliboev[3], O.Ch.Doniyorov[4],

[1,3,4]Tashkent institute of irrigation and agricultural mechanization engineers
Address: 39, Qori Niyaziy str., 100000, Tashkent city, Republic of Uzbekistan
E-mail: [1]a.plakhtiev@mail.ru, phone: + 998-90-943-59-25;
[2]Triple Point Engineering LLC
Address: 1, Beshagach str., 100066, Tashkent city, Republic of Uzbekistan
E-mail: gazievgayrat@gmail.com, phone: + 998-95-513-43-33.

Abstract: *In communication and communication devices, power equipment, relay protection and automation terminals, in the electric power industry of "smart" cities and homes, in industry, in railway transport, microprocessor-based relay protection and automation devices, distributed generation installations, including renewable energy sources, and electricity storage, as well as "intelligent" automated information and measurement systems are beginning to be used. Contactless converters of direct and alternating currents of control and control systems are widely used in them. Their disadvantages are a narrow range of controlled currents, large dimensions and weight. Therefore, it is important to eliminate them. The paper discusses the general principles of construction of contactless converters of large direct currents, the main requirements for them, and shows the results of the development of one of the options proposed by us, universal contactless magneto-modulation converters of large direct currents with an extended range for various control and control systems. They differ from the known ones by an extended controlled range with small dimensions and weight, and increased accuracy and sensitivity. The converter has a simple and technological design with low material consumption and cost, and can control large direct currents, as well as alternating currents, without contact. The paper considers the errors from external magnetic fields of universal contactless converters of control and control systems. It is shown that the error from the external magnetic field does not exceed 0.08% if the number of sections of the measuring winding is even and with their symmetrical arrangement, and with their even increase-the error decreases. At the same time, the developed contactless converters can be widely used in industry, metallurgy, railway transport, agriculture, water and farming, as well as in the electric power industry of "smart" cities and homes and for checking electric meters at the place of their installation.*

Key words: *non-contact measurement, magnetic modulation converter, meter verification, renewable energy sources, laser installation, split magnetic circuit, integrating circuit, distributed magnetic parameters.*

Аннотация: *Алоқа ва алоқа қурилмаларида, энергетик ускуналарда, реле ҳимояси ва автоматлаштириш терминалларида, ақлли шаҳарлар ва уйларнинг электр энергетикасида, саноатда, темир йўл транспортида микропроцессорга асосланган реле ҳимояси ва автоматлаштириш қурилмалари, қайта тикланадиган энергия манбалари, шу жумладан, тақсимланган генерация қурилмалари, электр энергияси, шунингдек "интеллектуал" автоматлаштирилган ахборот ва ўлчаш тизимлари қўллланила бошланди. Уларда кузатув ва бошқариш тизимларининг тўғридан-тўғри ва ўзгарувчан токларининг контактсиз конверторлари кенг қўлланилади. Уларнинг камчиликлари тор доирадаги бошқариладиган токлар, катта ўлчамлар ва оғирликдир. Шунинг учун уларни бартараф қилиш муҳим саналади. Ушбу мақолада контактсиз юқори доимий ток конверторларини тузилишининг умумий принциплари, уларга қўйиладиган асосий талаблар кўриб чиқилган ва биз таклиф қилган вариантлардан бирини ишлаб чиқиш натижалари кўрсатилган, ҳар хил кузатиш ва бошқариш тизимлари учун кенгайтирилган диапазонга эга универсал доимий магнит-модуляцияли юқори токли конверторлар таклиф этилган. Улар маълум бўлганларидан кичик ўлчамлари ва вазни, яхшиланган аниқлиги ва сезгирлиги, кенгайтирилган бошқариладиган диапазони билан фарқланади. Конвертер оддий ва технологик дизайнга эга бўлиб, материал кам сарфланади ва арзон таннархга эга ҳамда бевосита катта оқимларни, шунингдек ўзгарувчан токларни контактсиз бошқариши мумкин. Мақолада ташқи магнит майдонларини назорат қилиш ва бошқариш тизимларининг универсал контактсиз конверторларини хатоликларини кўриб чиқилган. Агар ўлчаш ўрамлари* *секторининг сони жуфт ва улар носимметрик жойлашган бўлса, ташқи магнит майдонининг хатолиги 0,08 % дан ошмаслиги ва уларнинг сони тоқ бўлса, хатолик камайиши кўрсатилган. Шу билан биргаликда, ишлаб чиқарилган контактсиз конверторлар саноат, металлургия, темир йўл транспорти, қишлоқ хўжалиги, сув ва фермер хўжалигида, шунингдек, ақлли шаҳарлар ва уйларнинг электр энергетикасида ва электр ҳисоблагичларни ўрнатиш жойларида қиёслашда кенг қўлланилиши мумкин.*

Таянч сўзлар: *контактсиз ўлчаш, магнит-модуляцияли ўзгарткич, ҳисоблагичларни қиёслаш, қайта тикланадиган энергия манбалари, лазер қурилмаси, бўлинадиган магнитўтказгич, интегралловчи контур, тақсимланган магнит параметрлари.*

Аннотация. *В устройствах связи и коммуникации, силовом оборудовании, терминалах релейных защит и автоматики, в электроэнергетике “умных” городов и домов, в промышленности, на железнодорожном транспорте начинают применяться микропроцессорные устройства релейной защиты и автоматики, установки распределенной генерации, включая возобновляемые источники энергии, и накопители электроэнергии, а также «интеллектуальные» автоматизированные информационно-измерительные системы. В них широко применяются бесконтактные преобразователи постоянного и переменного токов систем контроля и управления. Их недостатки – узкий диапазон контролируемых токов, большие габариты и масса. Поэтому важным является их устранение. В работе рассмотрены общие принципы построения бесконтактных преобразователей больших постоянных токов, основные требования к ним и показаны результаты разработки одного из вариантов, предложенных нами, универсальных бесконтактных магнитомодуляционных преобразователей больших постоянных токов с расширенным диапазоном для различных систем контроля и управления. Они отличаются от известных расширенным контролируемым диапазоном при малых габаритах и массе и повышенными точностью и чувствительностью. Преобразователь имеет простую и технологичную конструкцию при низких их материалоемкости и стоимости и может бесконтактно контролировать большие постоянные токи, а также и переменные токи. В работе рассмотрены погрешности от внешних магнитных полей универсальных бесконтактных преобразователей систем контроля и управления. Показано, что погрешность от внешнего магнитного поля не превышает 0,08%, если количество секций измерительной обмотки будет четным и при их симметричном расположении, а при их четном увеличении – погрешность уменьшается. При этом разработанные бесконтактные преобразователи могут широко применяться в промышленности, металлургии, на железнодорожном транспорте, в сельском, водном и фермерских хозяйствах, а также и в электроэнергетике “умных” городов и домов и для поверки электрических счетчиков на месте их установки.*

Ключевые слова: *бесконтактное измерение, магнитомодуляционный преобразователь, поверка счетчиков, возобновляемые источники энергии, лазерная установка, разъемный магнитопровод, интегрирующий контур, распределенные магнитные параметры.*

Introduction

The use of automated monitoring and control systems for various technological and physical processes in industry, metallurgy, and the agro-industrial sphere is characterized by the widespread use of primary means of collecting and processing information [1]. At the same time, the primary converter is a link of any information - measuring or control system and almost completely determines its metrological characteristics. Losses in the accuracy and reliability of the final result associated with the unsuccessful use of the primary converter are unable to restore even the most perfect information transformation system. The task becomes much more complicated in case of exposure to unstable factors, such as changes in temperature and humidity of the environment, the influence of corrosive media, electric and magnetic fields, vibrations, radiation, etc.

The need to convert large currents in various sectors of the national economy and, in particular, in the chemical industry, on railway transport, in metallurgy, land reclamation, irrigation and in agriculture in general, arises when monitoring and controlling the operating modes of powerful electric motors, substations and various consumers, where used non-contact measuring ferromagnetic transducers of high currents (FTHC) [4,5].

The need to break the current circuit for the temporary switching on of electrical measuring instruments, the presence of large power losses in the measuring current transformers and shunts, the undesirability or impossibility of breaking the circuit under the conditions of the technological process, as well as the safety requirements, led to the contactless conversion and measurement of large direct and alternating currents in circuits without their break, i.e. without destroying the integrity of the busbar [5,6].

Consideration of the issues of converting large direct currents (LDC) in electric power systems and electrical technological installations showed that one of the reasons for their low efficiency is the unsatisfactory technical characteristics of their secondary systems - control and monitoring systems for the operating modes of electrical power and electrical technological installations and, in particular, used in them FTHC. It is noted that FTHCs used in secondary systems of electric power systems and electrical installations should have an adjustable conversion range, better dynamic properties in transient modes of operation of electrical power systems and electrical installations, as well as stability of characteristics under extreme operating conditions [7 - 28].

When considering the places of non-destructive contactless testing of high currents, the main requirements for FTHC were identified. These include: high accuracy, reliability, sensitivity, low weight, dimensions, material consumption and cost, manufacturability of design, absence of errors from the influence of external magnetic fields, a reverse bus with a current from the center of the integrating circuit, ferromagnetic masses, absence of galvanic coupling between the measured alternating current and the measuring circuit and the presence in some cases of the possibility of both a fixed regulation of the sensitivity of the transducers in a wide range of convertible large alternating currents and the flexibility of the integrating circuit, and the design of the FTHC both portable and stationary [29 - 56].

In this regard, it is very important to develop and study such FTHCs that would have an extended range of convertible high currents with small dimensions and weight and increased accuracy, a simplified and technological design with low material consumption and cost [57, 58].

The solution to this problem can be facilitated by the development of universal magnetomodulation contactless converters (UCC) of control and management systems in industrial and agroelectric power engineering.

Research methods and results obtained

The main tasks that need to be solved in the design of UCCs in accordance with modern trends in the development of measuring instruments and conversions of high currents are mainly expanding the range of measured and converted values of high currents, expanding their frequency range in the case of alternating currents, increasing accuracy and sensitivity, decreasing weight and overall dimensions of UCC [40]. Most often, these tasks must be solved in aggregate for one UCC, choosing circuits and designs that simultaneously satisfy the requirements of a wide range of linearity of the static characteristic, a low threshold of sensitivity and a wide controlled current range with a small volume and low weight - overall characteristics of the UCC. In this regard, it is worthy of special attention to consider ways and methods,

It is shown that one of the effective possibilities of expanding the range of linearity of the UCC and reducing the sensitivity threshold is to increase the length of the split magnetic circuit of the UCC and its cross-sectional area to the maximum permissible size [2].

We have developed a number of UCCs, in which the set tasks are solved by using in the developed converters special designs of detachable closed magnetic circuits with transversely and longitudinally distributed magnetic parameters and an increased length of the working magnetic flux path over steel [2,40]. Next, we will consider the design features of one of the developed UCC and investigate its errors from the influence of external magnetic fields.

A generalized version of the developed UFT is shown partially with the main dimensions in Fig. 1. This design is developed on the basis of the UCC [11] and is a UCC with transversely and longitudinally distributed magnetic parameters. It features increased sensitivity and an extended range of converted currents. UCC contains a closed magnetic circuit, consisting of two groups of trapezoidal ferromagnetic elements 1 and 2. The first group in the upper ring includes identical ferromagnetic elements 1 and the second group - in the lower ring - also includes identical plate-like ferromagnetic elements 2 with the same gaps between them. Ferromagnetic elements 1 and 2 are assembled from separate plates made of thin sheet electrical steel. Each ferromagnetic element has two through holes, through each of which a modulation winding is wound, consisting of sections 4 and 6. Sections 4 and 6 are connected in series and according to. A measuring winding 5 is wound between the through-holes over the modulation winding. All measuring windings are connected in series with each other and closed to a measuring device, and the modulation windings are also connected in series and connected to a stable AC source (not shown in Fig. 1). In order to freely grip the bus 7 with controlled current, the closed magnetic circuit 1 is made detachable. The series connection of the modulation windings 4 and 6 with each other in the presence of alternating current and the arrangement of the measuring windings 5 in the intervals between the through holes in the ferromagnetic elements allowed Sections 4 and 6 are connected in series and according to. A measuring winding 5 is wound over the modulation winding between the through holes. All measuring windings are connected in series with each other and closed to the measuring device, and the modulation windings are also connected in series and connected to a stable AC source (not shown in Fig. 1). In order to freely grip the bus 7 with controlled current, the closed magnetic circuit 1 is made detachable. The series connection of the modulation windings 4 and 6 with each other in the presence of alternating current and the arrangement of the measuring windings 5 in the intervals between the through holes in the ferromagnetic elements allowed Sections 4 and 6 are connected in series and according to. A measuring winding 5 is wound between the through-holes over the modulation winding. All measuring windings are connected in series with each other and closed to a measuring device, and the modulation windings are also connected in series and connected to a stable AC source (not shown in Fig. 1). In order to freely grip the bus 7 with controlled current, the closed magnetic circuit 1 is made detachable. The series connection of the modulation windings 4 and 6 with each other in the presence of alternating current and the arrangement of the measuring windings 5 in the intervals between the through holes in the ferromagnetic elements allowed All measuring windings are connected in series with each other and closed to the measuring device, and the modulation windings are also connected in series and connected to a stable AC source (not shown in Fig. 1). In order to freely grip the bus 7 with controlled current, the closed magnetic circuit 1 is made detachable. The series connection of the modulation windings 4 and 6 with each other in the presence of alternating current and the arrangement of the measuring windings 5 in the intervals between the through holes in the ferromagnetic elements allowed All measuring windings are connected in series with each other and closed to the measuring device, and the modulation windings are also connected in series and connected to a stable AC source (not shown in Fig. 1). In order to freely grip the bus 7 with controlled current, the closed magnetic circuit 1 is made detachable. The series connection of the modulation windings 4 and 6 with each other in the presence of alternating current and the arrangement of the measuring windings 5 in the intervals between the through holes in the ferromagnetic elements allowed to carry out longitudinal modulation of the magnetic resistance of the magnetic circuit along the path of the working flow Φ, created by a controlled direct current, and induce an EMF in the measuring windings 5, depending on the converted direct current. The developed DCL can also control alternating current. In this case, there should be no alternating current in sections 4 and 6 of the modulation winding.

The expansion of the upper limit of the controlled direct current in the developed DCC design is carried out by increasing the length of the working magnetic flux along the steel of the magnetic circuit elements and including transverse and longitudinal air gaps in its path, i.e., making a split magnetic circuit with transversely and longitudinally distributed magnetic parameters.

To control the BPT with a detachable magnetic circuit, the UCC cover the bus 7. Due to the modulation ampere-turns, the split magnetic circuit is in a saturated state during each half-period of the supply voltage. In this case, the permeability of the magnetic circuit for the longitudinal field created by the controlled current decreases sharply. At the moment when the modulation current passes through zero, the magnetic core permeability rises to the initial value. Thus, with the stability of the modulation ampere turns, an EMF of double frequency will be induced in the measuring winding, depending on the controlled current.

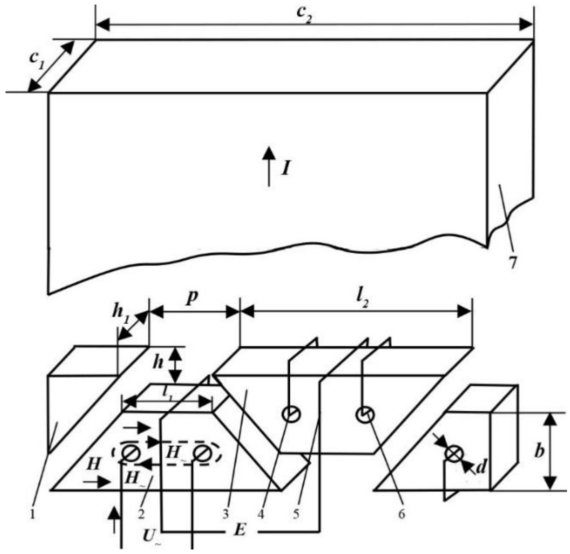

Fig. 1. ***Part of a universal non-contact magneto-modulation converter for large direct currents.***

With the mutual movement of halves 2 and 3 of the split magnetic circuit of the UCC, the size of the gaps between the trapezoids changes, leading to a change in the whole of the magnetic resistance of the magnetic circuit in the path of the working magnetic flux Φ created by a controlled direct current. This leads to a change in the limits of the controlled current, i.e. allows you to make the UCC multi-limit.

For widespread use of the developed DCS in multidisciplinary monitoring and control systems, they must be free from the influence of external magnetic fields. Therefore, let us investigate the influence of external magnetic fields on the developed CCA.

In the presence of an external magnetic field, an additional error appears UTP caused by induction of EMF in the measuring winding from the tangential component of the external magnetic field strength.

In fig. 2 shows the outline UTP in an external uniform magnetic field in the absence of a magnetic circuit in it. The tangent component of the external magnetic field strength $H_{вн}$ at any point of the contour is

$$H_{Tвн} = H_{вн} \sin\varphi\,, \qquad (1)$$

where φ Is the central corner.

Consideration of the influence of the magnetic circuit UTP is carried out using the design parameter Pk. Then the expression for the tangential component of the external magnetic field strength at any pointdetachable magnetic circuit UCC can write

$$H_{Tвн\mu} = H_{Tвн} \cdot П_к = H_{вн} П_к \sin\varphi\,. \qquad (2)$$

Multiplying both parts of (2) by the coefficient of approximation of the magnetization curve a_2, we obtain the dimensionless value of the tangent component of the external magnetic field strength at any point detachable magnetic circuit UCC as

$$a_2 H_{Tвн\mu} = H_{xвн} \sin\varphi\,, \qquad (3)$$

where

$$H_{xвn} = a_2 H_{\text{vnpk}} ... \qquad (4)$$

The reduced additive error due to the influence of an external magnetic field with an approximation sufficient for analysis is determined from the expression

$$\Delta_{внA} = \frac{\Delta E_{\Sigma вн}}{E_{max}} ... \qquad (5)$$

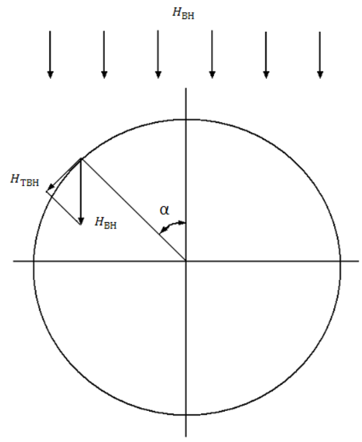

Fig. 2. ***Circuit UTP in an external uniform magnetic field in the absence of a magnetic circuit in it.***

Static characteristic UTP is

$$E_{cp} = \frac{\omega a_1 w_u S}{\pi} \left[2arctgH_x - arctg(H_x - 1{,}65) - arctg(H_x + 1{,}65)\right] \qquad (6)$$

or

$$E_{cp} = \frac{E_б}{\pi} \left[2arctgH_x - arctg(H_x - 1{,}65) - arctg(H_x + 1{,}65)\right]. \qquad (7)$$

Here E_b is the base value of the output EMF, equal to

$$E_б = \omega a_1 w_u S, \qquad (8)$$

H_x - the strength of the magnetic field penetrating the turns of the measuring winding, which is a function of the controlled current at a given value of the modulation current and carries information about the design parameters of the split closed magnetic circuit and the grade of steel used in the magnetic circuit.

Substituting instead of H_x in (7) the value (3) and dividing the result by 2π, we obtain the change in the EMF from the external magnetic field at each point of the circuit integration provided that the entire measuring winding is evenly distributed over contour in the form

$$\Delta e_{\varphi ВН} = \frac{E_б}{2\pi^2} \left[2arctgH_{x вн} \sin\varphi - arctg(H_{x вн} - 1{,}65) - arctg(H_{x вн} + 1{,}65)\right]. \qquad (9)$$

Here $\frac{E_б}{2\pi}$ - the base value of the output EMF for each angular radian of the DCC integrating circuit.

To simplify the calculation of the obtained expression, let us take each section of the measuring winding concentrated at a point. Then the central angle of each measurement point in the integrating circuit of the DCS is equal to

$$\varphi = i2\pi / m, \qquad (10)$$

where m is the number of sections of the measuring winding; i = 1, 2,…, m.

In this case, the average EMF of the DCS is equal to

$$\Delta E_{\Sigma вн} = \frac{E_б}{\pi m} \left[2arctgH_{x_{ВН}} \sin i\frac{2\pi}{m} - arctg\left(H_{x_{ВН}} \sin i\frac{2\pi}{m} - 1{,}65\right) - arctg(H_{x_{ВН}} \sin i\frac{2\pi}{m} + 1{,}65)\right]. \qquad (11)$$

The maximum value of the output EMF of the DCC at Hx = 0.7, in turn, is

$$E_{max} = 0{,}65E_b. \qquad (12)$$

Substituting (7) and (11) into (5) and taking into account (12), we obtain the reduced additive error from the influence of an external magnetic field

$$\Delta E_{внA} = \frac{0{,}53}{m} \sum_{i=1}^{m} \left[2arctgH_{x_{ВН}} \sin i\frac{2\pi}{m} - arctg\left(H_{x_{ВН}} \sin i\frac{2\pi}{m} - 1{,}65\right) - arctg(H_{x_{ВН}} \sin i\frac{2\pi}{m} + 1{,}65)\right] \qquad (13)$$

By expression (13), the reduced additive error from the influence of an external magnetic field was determined at m = 6; 12 and 18. The calculation results showed that $\Delta_{внA}$ does not exceed 0.06% at m = 6 and $H_{хвн}$ = 1.2. With an even increase in m, the error decreases.

Experiments conducted with the UTP, the parameters of which (see Fig.1): the outer diameter of the split closed magnetic circuit $D_{внеш}$ = 0.205 m; internal diameter of the split closed magnetic circuit $D_{внутр}$ = 0.175 m; $h_1 = 2.8 \cdot 10^{-3}$ m; $h = 1 \cdot 10^{-3}$ m; $p = 2 \cdot 10^{-3}$ m; $b = 15 \cdot 10^{-3}$ m; horizontal length of the inclined part of the ferromagnetic elements $X_m = 17.9 \cdot 10^{-3}$ m; the number of ferromagnetic elements $n_\sum = 30$, and the split magnetic core is made of cold-rolled steel 3414 with a sheet thickness of 0.35 mm, for which the approximation coefficients are a_1 = 1.853 T and $a_2 = 0.714 \cdot 10^{-2}$ m/A, showed that the reduced additive error from the influence of an external magnetic field does not exceed 0.08%, if the number of sections of the measuring winding is even $t = 2k$, where $k = 1, 2, ..., \frac{m}{2}$ and with their symmetrical arrangement.

Conclusion

Developed universal non-contact wide-range magnetomodulation converters of large direct and also alternating currents for modern control and management systems in metallurgy, railway transport, solar and laser technology, renewable energy sources, industry, agro-industrial sphere, as well as for verification of electric meters at the place of their installation, characterized by an extended controlled range of convertible direct currents with small dimensions and weight, increased accuracy and sensitivity, simplicity and manufacturability of the design with low material consumption and cost and the possibility of contactless control of direct and alternating currents with an error 1.5%, as well as for the control of electricity and verification of electricity meters at the place of their installation. The errors of universal contactless converters of monitoring and control systems from external magnetic fields are considered. The results of their research are presented. Shown that the error from the external magnetic field does not exceed 0.08% if the number of sections of the measuring winding is even and with their symmetrical arrangement, and when they increase evenly, the error decreases.

References:

1. M.K.Kazakov, “Methods and means of measuring high voltages and high amperage currents in power engineering”, Author's abstract Doctoral dissertation thesis, 1998.
2. A.M.Plakhtiev, “Effective informational contactless converters for modern monitoring and control systems in the agro-industrial complex”, *International Scientific and Practical Conference. "Agrarian science - to agriculture,* Collection of scientific articles, Barnaul, pp. 37-39, 2017.
3. N.G.Semenko, Yu.A.Gamazov, *Measuring transducers of large electric currents and their metrological support*. Moscow: Publishing house of standards, 1984, 132 p.
4. Mukhamedkhanov UT 2008 Concepts and methods of constructing quality control systems for technological environments of industrial production. Abstract of dissertation of Doctor of technical Sciences.
5. V.A.Andreev, *Relay protection and automation of power supply systems*. Moscow: Higher school, 1991, 496 p.
6. N.R.Yusupbekov, H.Z.Igamberdiev, Sh.M.Gulyamov, F.T.Adilov, “Technologies of automation of industrial processes”, *Chemical technology. Managment control*, no. 1, pp. 50-55, 2007.
7. S.A.Spektor, *Measurement of large constant currents*. Leningrad: Energy, 1988, 136 p.
8. O.Bolotin, G.Portnoy, K.Razumovsky, “Primary sensors for energy enterprises”, *Energy security and energy saving*, no. 5, pp. 28-32, 2012.
9. A.Danilov, “Modern industrial current sensors”, *Modern electronics*, no. 10, pp. 38-43, 2004.
10. O.Bolotin, G.Portnoy, K.Razumovsky, “Modern sensors for measuring current and voltage”, *ISUP*, no. 1(61), pp. 18-25, 2016.
11. M.Gilardi, “New Horizons in Hall Effect Current Sensor Technology”, *Power Electronics*, no. 3, pp. 48-52, 2013.
12. A.M.Plakhtiev, G.P.Petrov, H.S.Minikeev, “Meter of large direct currents”, A.S. 792152, IPC G01R 19/00, 2735180/18 - 21; Stated 11.03.79; Publ. 12/30/1980, Bul. 48.
13. A.L.Gurtovtsev, “Optical transformers and current converters. Principles of operation, device, characteristics”, *Electrical Engineering News*, no. 5, pp. 48 -52, 2010.
14. B.Kh.Khushbokov, “Multi-range current transformers for control systems of power supply devices for railway transport”, Dis. ... can. those. Sciences, Tashkent State Technical University, Tashkent, 2010.

15. S.F.Amirov, A.M.Safarov, D.Sh.Rustamov, N.O.Ataullaev, *Electromagnetic converters of high currents for traction power supply systems*. Tashkent: Fan, 2019, 279 p.
16. V.E.Kazansky, *Measuring current transducers in relay protection*. Moscow: Energoatomizdat, 1988, 240 p.
17. S.A.Zaitsev, D.D.Gribonov, A.N.Tolstov, *Control and measuring devices and instruments*. Moscow: Academy, 2006, 463 p.
18. A.M.Safarov, “Application of current converters in the systems of technical diagnostics of electrical equipment”, *Proceedings of the International Scientific and Technical Conference "Current state and prospects of energy development"*, Tashkent, Tashkent State Technical University, 2006, pp. 173-175.
19. U.T.Mukhamedkhanov, Concepts and methods of constructing quality control systems for technological environments of industrial production, Abstract dis. doc. those. Sciences, Tashkent, 2008.
20. D.Borkman, “Hochstrommessungmit Hallgeneratoren”, *Elekrie*, vol. 18, no. 2, pp. 46-50, 1997.
21. W.Krämer, “Gleichstrom - Wandlerschaltung hoher Genauigkeitl für p. 65 - 71 wellige Gleichstrom”, *ETZ-A*, no. 18, pp. 28 – 33, 1996.
22. F.Lappe, “Ein neues Meβgerät für hohe Gleichström”, *Chemi-Ingenier-Technick*, vol. 42, no. 19, pp. 1228-1229, 1998.
23. T.N. Yuki, “Electromagnetic noncontacting measuring apparatus”, US Patent no. 5234844, MKI G01R 27/04, NCI 324 - 58 dated, 11.18.2016.
24. Nils Bardahl, “Einrichtung zur Erfassung des Belastungsstromes in Hochstromanlagen”, German Patent no. 3148654, Cl. 21e36 / 01, 28.11.2016.
25. E.M.Eadie, “Complete specification improvements in multi-range hook-on electrical indication instrument”, UK Patent no. 3966443, NCI G1U, 21.12.2015.
26. Standard Telefones & Cables LTD, “Current monitoring circults including hall effect devices”, UK Patent no. 4575111, MKI G01R 19/165, NCI GIU, 17.09.2016.
27. TOKYO SHIBAURA, “Transducers”, UK patent no. 3036984, MKI G01R 19/22, NCI GIU dated 02.07.2017.
28. E.A.Meierovich, L.I.Andreevskaya, “Dispositif paur la mesurede I'intesite du courant”, French patent no. 4347944, MKI G01R, 24.02.2017.
29. Bernard Georges Alhadef, “Transducteur electrique comportani un moyen de codage dun parameter du transducteur”, French Patent no. 3955731, MKI G01D 18/00, 3/04; G01F 25/00, 02.01.2000.
30. Reich, Ernö, “Elektricky měřici přistroj”, Czech Patent no. 2145015, MKI 21e3601, 15.04.2018.
31. Lanczi Zoltan, “Aramlokest mérö müszer”, Hungarian Patent no. 2146340, MKI 21e 29-36, 30.11.2015.
32. Hitachi, Ltd., Chiyoda-ku Tokyo 100 (JP), “Magnetoelectrical transducer”, Japan patent no. 3257766, MKI G01D 5/16, 18.08.2017.
33. V.N.Brodovsky, B.M. Korzhanov, “Current transformer”, A.C. 3592239, MPK21e3601, Bul. 4, 05.01.2017.
34. Yoshihiro Konno, Masaru Sasaki, “Electric current measure apparatus”, Japanese patent MKI G01R, CN204154795U, 21.05.2009.
35. Chjan Li, “Stripping electrical measuring one meter”, MKI G01R 19, CN204154795U, 02.11.2015.
36. Michel Lynn, John Shie, “Power amplifier saturation detection”, MKI G01R, US10224917B2, 05.03.2019.
37. Andreas Jurisch, “Method of measuring current in a conductor in an ac transmission network”, MKI G01R, WO19945020765A1, 03.08.1995.
38. Horst Knoedgen, Frank Kronmueller, “Highly accurate current measurement”, MKI G01R, EP2821799A1, 13.02.2019.
39. Rudolf Gati, Markus Abplanalp, “Configuration of magnetoriesistire sensors for current measurement”, MKI G01R, ES2591283T3, 22.07.2008.
40. Woifgang Grieshaber, Jean-Pierre Dupraz, “Method of opening a bypass switch of a high voltage direct current network”, MKI G01R, CA284893OC, 09.21.2011.
41. Z. Wenlong, Z. Minxi, Y. Guoliang, V. Petukhov, Vsévolod Mymrin and G. Evangelos, “Flow Resistance in Dredged Soi1 under a Vacuum Preloading System with Vertical Drainage Boards”, *Coastal Education and Research Foundation*, vol. 36, no. 2, pp 327-338.
42. S. Ziegler, R. Woodward and H.C. Herbert, “Current Sensing Techniques: A Review”, *IEEE Sensors Journal*, vol. 9(4), pp. 354 – 376, 2009.
43. Y.Wu, Y.Liu, F.Li, Y.Zhou, J.Ding and Li Run-Wei, “Sensors and Actuators”, *B 2018 Chemical 276*, pp. 540-544, 2018, https://doi.org/10.1016/i.snb.2018.08.083
44. A.Pinar, B.Wijnen, G.C.Anzalone, T.C.Havens, P.G.Sanders, J.M.Pearce and J.Sens, “Low-cost open-source voltage and current monitor for gas metal arc weld 3D printing”, 2015. 10.1155/2015/876714
45. T.Makoto, O.Yasunori, I.Michihira, Y.Chihiro and W.Jianging, “Non-Contact Measurement Method for High Frequency Impedance of Load at the End of Wire Harness”, *SAE International Journal of Engines*, vol. 10, no. 4 pp 2034-2039, 2017.
46. T.Ray, F.Smith, P.M.Jjunju, S.Young, Taylor Stephen and Simon Maher, “A physical model for low-frequency electromagnetic induction in the near field based on direct interaction between transmitter and receiver electrons”, *Mathematical, Physical and Engineering Sciences*, vol. 472, no. 2191, pp. 1-13, 2016.

47. S.A.Mohammad, A.Aqueel, A.K.Zeeshan, R.Yasser, C.Ch.Rakan, K.Imran and Samir M Al- Shariff, “A Bibliographical Review of Electrical Vehicles (xEVs) Standards”, *SAE International Journal ofAlternative Powertrains*, vol. 7, no. 1, pp 63-98, 2018.
48. N.H.Duc and D.T.Huong, “Magnetic sensors based on piezoelectric – magnetostrictive composites J”, *Alloys and Compounds*, vol. 449, pp. 214-218, 2008.
49. P.Jun, J.Shuhai, B.Jiaming, Zh.Shuo, L.Jianben and Zh.Xing, “Recent Progress on Electromagnetic Field Measurement Based on Optical Sensors” *US National Library of Medicine and National Institutes ofHealth*, 2019, doi: 10.3390/s19132860.
50. K.Steiglitz, “Signal Standardization. In The Discrete Charm of the Machine: Why the World Became Digital”, Princeton; Oxford: Princeton University Press. (pp 22-42), 2019. doi: 10.2307/j.ctvc77c2g.6
51. J. Michael, Lenaeus, M. Tamer, Gamal El-Din, Christopher Ing, Karthik Ramanadane, Regis Pomes, Ning Zheng and William A. Catterall, “Structures of closed and open states of a voltage-gated sodium channel Proceedings the National Academy of Sciences of the United States of America”, vol. 114 no. 15, pp E3051-E3060, 2017.
52. H. Evangelos, “Magnetic Sensors. A special issue of Sensors”, *School of Electrical and Computer Engineering, National Technical University of Athen,* 15780 Athens, Greece, 2018.
53. L. Wei, Bing Liang, Zhenyuan Jia, Di Feng, Xintong Jiang, Xiao Li and Mengde Zhou, “High-Accuracy Calibration Based on Linearity Adjustment for Eddy Current Displacement Sensor Key Laboratory”, *Precision and Non-traditional Machining Technology of the Ministry Education*, no. 18(9), pp. 28-42, 2018, https://doi.org/10.3390/s18092842
54. P. Ripka, “Current sensors using magnetic materials”, *Journal of Optoelectronics and Advanced Materials*, no. 2, pp. 587 - 592, 2004.
55. S.Arya Krishna and Lizy Abraham, “Analysis of Different Hall Effect Current Sensors for Space Applications” *IJISET – International Journal of Innovative Science, Engineering and Technology*, no. 1(5), 2014.
56. G. Laimer and J.W.Kolar, “Design and experimental analysis of a DC to 1 MHz closed loop magnetoresistive current sensor”, *Twentieth Annual IEEE Applied Power Electronics Conference and Exposition*, pp. 1288-1292, 2005, 10.1109/APEC.2005.1453172
57. P. Maria-Alexandra, S. Jean-Michel and K.Maher, “Comparative Study on the Performance of Five Different Hall Effect Devices Sensors”, *US National Library of Medicine and National Institutes of Health*, no. 13(2), pp. 2093-2112, 2013, doi: 10.3390/s130202093
58. A.M.Plakhtiyev, S.U. Akhmedov, “Condition of application and development of contactless ferromagnetic converters in electrochemistry and metallurgy”, *Eighth World Conference on Intelligent Systems for Industrial Automation. WCIS – 2014*, Tashkent, 2014. pp. 326 – 329, 2014.
59. A.M.Plakhtiyev, G.A.Gaziev, “A study on Electrical Energy Measuring Device in installation place”, *Chemical Technology. Control and Management*, no. 4 (90), pp.25-29, 2019.