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The influence of a strong external magnetic field from a permanent magnet on a measurement accuracy of an inductive watt-hour meter

Abstract. *Stealing electricity using the influence of a strong neodymium magnet field on an induction meter is a significant problem of energy companies. Such a magnet, which is drawn close to the induction metering system, affects it operation falsifying its indications and damaging it permanently. The article presents the results of tests aimed at determination of the effect of an external magnetic field on the accuracy of measurements of the induction electricity meter.*

Streszczenie. *Istotnym problemem dla firm energetycznych jest kradzież energii elektrycznej poprzez oddziaływanie polem silnego magnesu neodymowego na licznik indukcyjny. Magnes taki, zbliżony do ustroju licznika indukcyjnego, wpływa na jego pracę fałszując jego wskazania i trwale go uszkadzając. W artykule przedstawia się wyniki badań mających na celu określenie wpływu zewnętrznego pola magnetycznego na dokładność pomiarów indukcyjnego licznika energii elektrycznej. (**Wpływ silnego zewnętrznego pola magnetycznego magnesu trwałego na dokładność pomiarów indukcyjnego licznika energii elektrycznej**).*

Keywords: inductive watt-hour meter, neodymium magnet, measurement accuracy, stealing electricity.
Słowa kluczowe: indukcyjny licznik energii elektrycznej, magnes neodymowy, dokładność pomiaru, kradzież energii elektrycznej.

Introduction

The indications of induction meters are the basis of determination of the amount of a financial liability between the recipient and supplier of electricity. Therefore, they should provide reliable measurement of the amount of consumed energy. Recently, however, stealing of electricity with a strong neodymium magnet [1 - 6] has been increasing, despite the fact that the design of meters, their performances, and legal metrological control are subject to a number of provisions: the standards [7, 8, 9], the instruction of the Central Office of Measures [10] and regulations [11, 12]. They describe in detail the requirements for electricity meters, but only in the newest standard [9] the issue of the influence of an external, strong magnetic field was included. The article presents the results of test of the effects of the application of neodymium magnets in the form of: an additional braking torque, negative energy measurement errors, increasing inrush current, changing a magnetic flux in a current and voltage core and degaussing the brake magnet of the meter and permanent damage to the meter system.

Properties of neodymium magnets

Neodymium magnets available in the free sale are the source of an appropriately strong magnetic field capable to disturb the operation of the meter. They are manufactured using methods of metallurgy of powders from rare earth element compounds: neodymium, iron and boron (Nd2Fe14B). They are characterised with an extremely strong magnetic field, several times stronger than the fields of other permanent magnets, such as Alnico or ferrite ones. In the test, a cylindrical neodymium magnet N42 of a diameter of D=70 mm and a height of H=30 mm was used. Figure 1 shows the value of magnetic induction B measured at a distance X from the surface of the magnet in the direction parallel to the axis of the magnet's symmetry (curve *a*) and in the direction perpendicular to it (curve *b*) [4]. This magnet, at a distance of ten-odd millimetres from its surface, generates a field of magnetic induction similar to induction in the brake magnet gap. Such a magnet can effectively disturb the operation of the meter through its cover [3, 4, 5]. If recipient inserts such neodymium magnet near the inductive watt-hour meter, the meter runs slowly than it should, so it can't measure correctly the consumption of electrical energy.

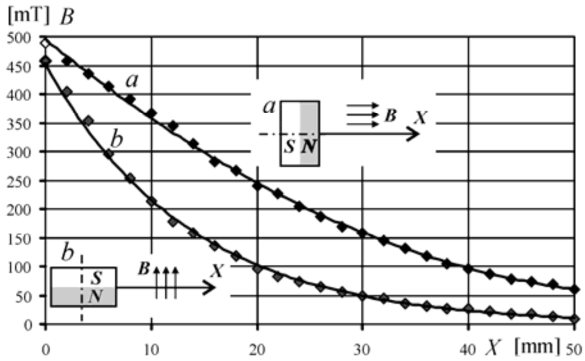

Fig.1. The value of magnetic induction B of permanent neodymium magnet N42, D = 70 mm, H = 30 mm measured at a distance X from the surface of the magnet in the direction parallel to the axis of the magnet's symmetry (curve *a*) and in the direction perpendicular to it (curve *b*)

Conducted tests

Tests of influence of the external impact of the permanent magnetic field on the inductive measuring system were conducted on the popular meters type 8A8d, whose internal brake magnets have induction B of approximately 250-320 mT. The basic current of the meter was I_b=5 A, maximum current I_{max}=40 A, the constant of the meter c=600 rev/kWh. Energy measurement errors δA were designated using power and time method [11, 12]:

$$\delta A = \frac{A_2 - A_1}{A_1} \cdot 100\% \qquad (1)$$

where: A_1 - the electricity measured before applying of external magnetic field, A_2 - the electricity measured after applying of external magnetic field.

Additional braking torque

Firstly, the formation of additional braking torque from the external magnetic field was studied. Figure 2 shows the breaking torque T_{ex} generated by the external neodymium magnet in relation to the braking torque T_b generated by the meter's internal magnet. Measurements were conducted after removal of the internal magnet, and the ratio of the braking torques T_{ex}/T_b was designated on the basis of the ratios of the times for n number of revolutions of the disc, as in the power and time method [11, 12]. Drawing closer the magnet on the distance X, the smallest allowed by the meter cover (12 mm), generates additional breaking torque T_{ex} of a value of c. 10% of the braking torque of the internal magnet T_b. However, resultant energy measurement error δA is smaller because of the simultaneous deterioration of the internal magnet field by the external field.

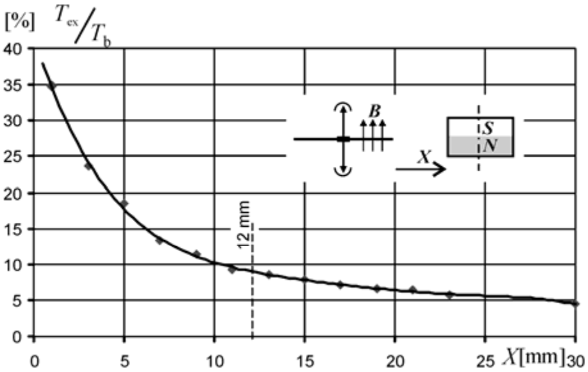

Fig.2. The breaking torque T_{ex} generated by the neodymium magnet in relation to the braking torque T_b generated by the meter's internal magnet versus distance X

Figure 3a shows the dependence of the energy measurement error δA as a function of load current I at parallel setting of the axis of symmetry of the magnet in relation to the axis of rotation of the disc that is to say the induction vector B of the external magnet field was perpendicular to the disc surface. The magnet was placed on the cover of the meter in a place giving the greatest slowdown of the disc revolutions, which was established during the earlier test [4].

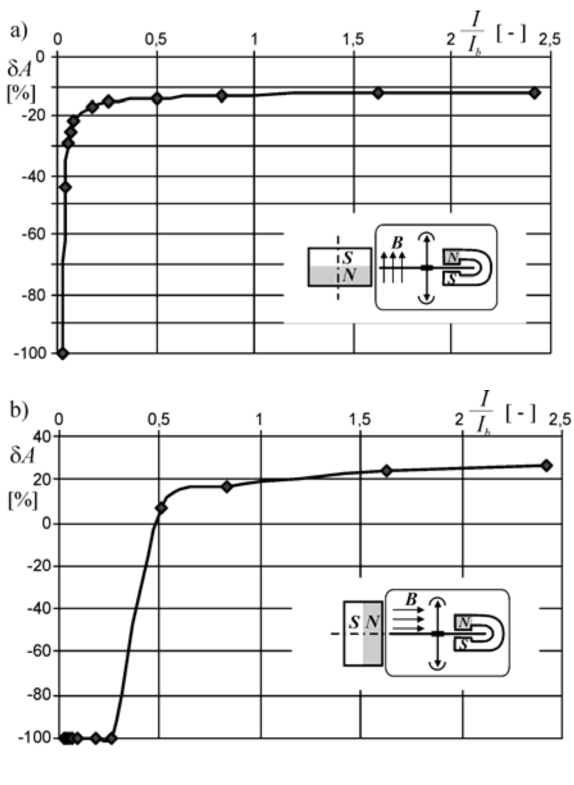

Fig.3. The energy measurement error versus relative load current at perpendicular (a) and parallel (b) setting of the external induction vector B to the disc surface

Large negative energy measurement errors δA (even 100 %) are for small current values. For larger currents, the error reaches a value of c. –10 %. Figure 3b shows the energy measurement errors at perpendicular setting of the axis of symmetry of the magnet in relation to the axis of rotation of the disc that is to say the induction vector B of the external magnet field was parallel to the disc surface. In this configuration, the additional breaking torque does not occur, the internal magnet field weakens, energy measurement errors are positive (c. 20 %). This magnet setting does not slow down revolutions of the disc, but it accelerates them.

Inrush current

As we can see on figure 3b, for small values of the currents, the error δA is large and negative (–100 %), because the inrush current of the meter increases and the disc does not revolve at all for currents smaller than 25 % of the basic current I_b. Figure 4 shows an idle running brake mounted in watt-hour meter. The external magnet located on the cover of the meter with the field parallel to the surface of the disc (fig. 3b) attracts a steel wire, which is a part of the idle running brake, so strongly that the disc stops at the new location. This way additional external magnetic field increases the braking moment and causes negative errors of electric energy measurement. That is why the inrush current increases even ten-odd times reaching values close to 25 % of the basic current. This allows for illegal power input of the order of 300 W. This effect is reversible and disappears after removal of the neodymium magnet.

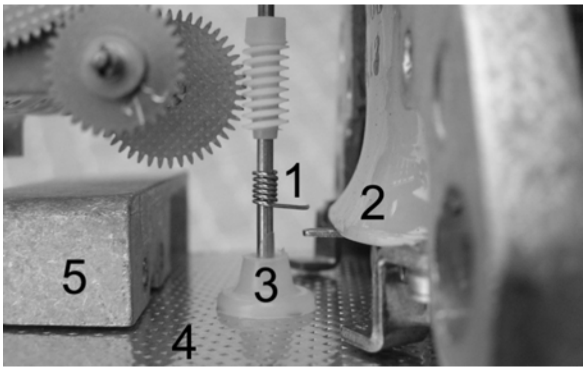

Fig.4. The idle running brake mounted in watt-hour meter: 1 - steel wire, 2 - voltage core, 3 - disc shaft, 4 - aluminium rotating disc, 5 - internal brake magnet

Magnetic flux of the voltage and current core

The current and voltage coils are also susceptible to the external magnetic field influence. The core of these coils closes the outer magnetic flux. As a result the measuring error becomes negative, but after removing the external field, energy meter returns to the previous state. In this case the interference process is reversible.

Figure 5 shows the influence of the external magnet field on a magnetic flux Φ_{max} of the voltage and current core. The value of magnetic fluxes Φ was measured with inductive probes. Due to the non-linearity of the magnetic circuit, the external magnetic field reduces the magnetic flux by c. 5 % in voltage core (fig. 5a) and c. 7 % in current core (fig. 5b). This causes negative energy measurement errors δA. This effect is not permanent and disappears after removal of the neodymium magnet.

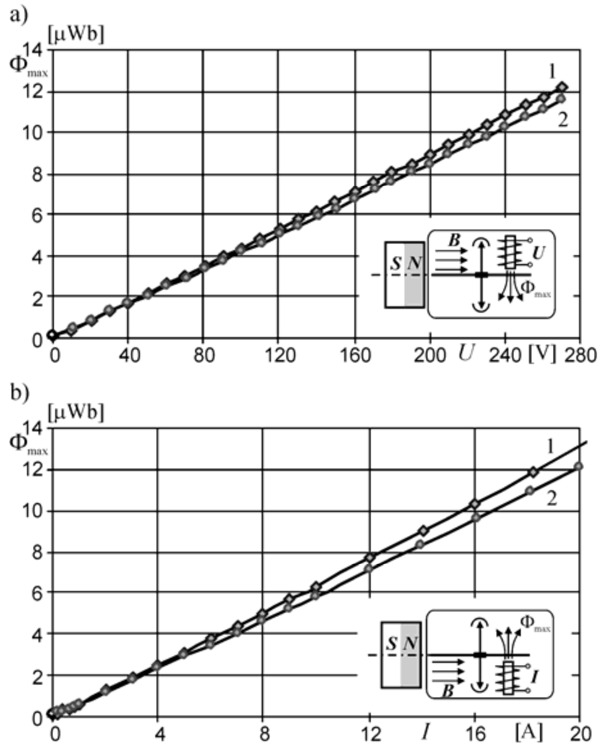

Fig.5. The influence of the external magnet field on a magnetic flux Φ_{max} of the voltage (a) and current core (b): 1 - without applying external field, 2 - with applying external field.

Degaussing effect of the internal brake magnet

The function of the internal magnet for a watt-hour meter is to produce a braking torque, which must be strictly proportional to the velocity of the rotating disc in such a way that the speed of rotation is proportional to the electric power flowing through meter. Some kinds of Alnico braking magnets used in induction watt-hour meters are shown in Figure 6.

Fig.6. Some kinds of Alnico braking magnets used in induction watt-hour meters

The brake magnet is the most susceptible element in inductive watt-hour meter to the external neodymium magnet. An attack with a strong external magnetic field on the braking magnet of the meter can lead to its permanent degaussing. After removing the external magnet the meter reading is higher than the real energy consumption. The degaussing effect of the internal brake magnet of the meter was examined with drawing the neodymium magnet closer to it. The obtained results are shown in Figure 7. Induction B of the field in the magnet gap was measured with a Hall effect meter. The bottom line shows the value of induction B in the magnet gap of the meter after drawing closer to it a neodymium magnet at a distance X, and the top line – after its repeated removal over a long distance. As close as at distance of 80 mm, the brake magnet field is weakened and regains its proper values after removal of the neodymium magnet. Permanent degaussing begins after drawing closer a neodymium magnet at a distance of 50 mm. Single placement of the magnet to the cover of the meter (X=20 mm) results in degaussing up to 50% of the initial value of induction B.

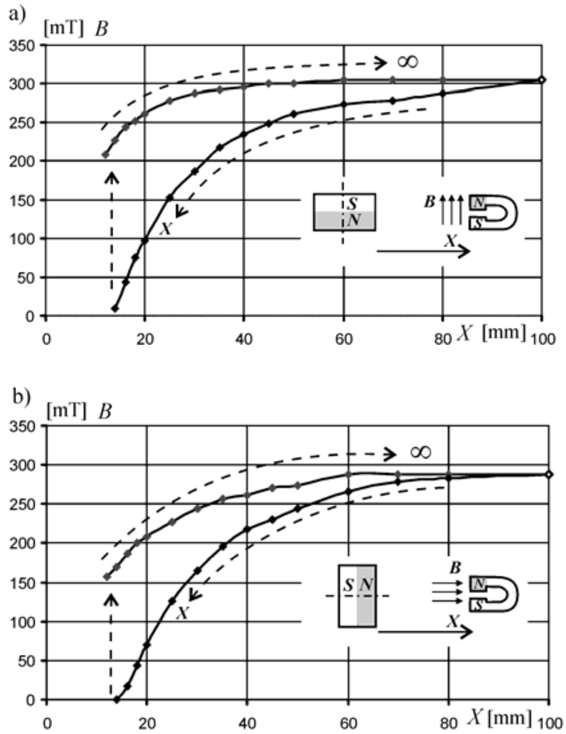

Fig.7. The degaussing effect of the internal brake magnet by parallel (a) and perpendicular (b) external field

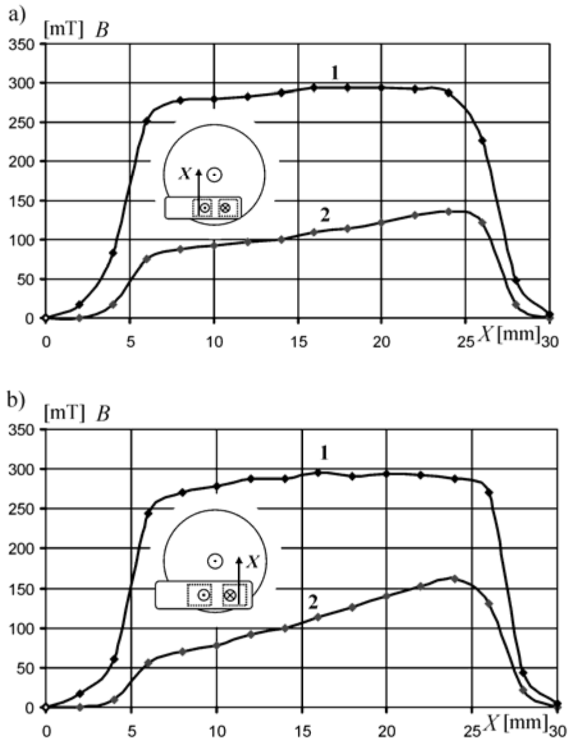

Fig.8. The field distribution in the left gap (a) and in the right one (b) of the brake magnet before (1) and after (2) degaussing

After removing the external magnet such meter indicates very high positive errors and must be replaced. Moreover, a distinct field irregularities have been found in the demagnetised permanent magnet in the meter, which might be used as an evidence of using the neodymium magnet for the electric energy theft. The field distribution in the gap of the internal magnet in the direction parallel to the radius of the disc before and after degaussing is of particular interest, which was shown in figure 8, separately for the field in the left gap (a) and the right one (b). Distribution of field before degaussing (1) even, and after degaussing (2), the field is weaker and shows a clear unevenness: the external part of the magnet closer to the cover is far more degaussed than on the internal one, where induction is 2 – 3 times greater. Subsequent drawing closer a neodymium magnet increasingly impair the brake magnet field, but the field distribution remains clearly uneven. This effect is very distinctive and is a clear evidence of the use of the neodymium magnet, since the effects of ageing, the impact of temperature, mechanical shocks may also weaken the permanent magnet field, but do not cause such an effect of field unevenness.

Watt-hour meter after applying strong external field

An important consequence of the brake magnet degaussing is a significant increase in energy measurement errors δA. Figure 9 shows the errors of the meter before (1), after single (2), and after repeated (3) drawing the neodymium magnet closer to its cover. Errors have a positive sign and the meter significantly overvalues the indication to the disadvantage of the recipient. Each successive drawing the magnet closer to the meter increases this effect and, eventually, the errors can reach up to several hundred % [2]. This counter does not meet any of the requirements [7-12], and its replacement for a new item is necessary.

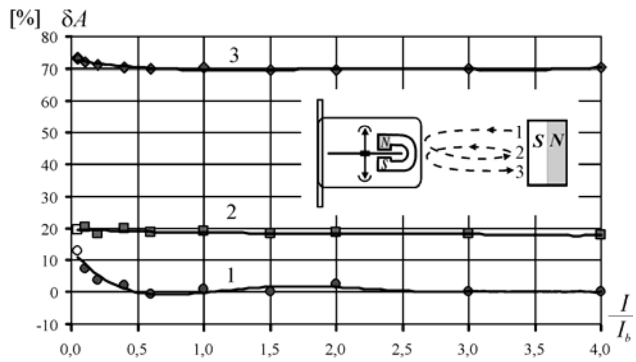

Fig.9. Errors of energy meters before (1) and after (2, 3) degaussing of the brake magnet

Conclusions

Influence of an external field of a strong permanent magnet on the operation of the induction electricity meter is manifold. An additional breaking torque causing negative energy measurement errors up to c. –10% for large currents occurs. The inrush current of the meter also increases and power input of the order of a few hundred watts without billing, but this effect is reversible and disappears after removal of the magnet. At the same time, the internal breaking magnet is degaussed permanently, which always destroys the measurement system of the meter. A strongly uneven distribution of the magnetic field of the meter's permanent magnet gap arises, which allows to explicitly confirm the use of the neodymium magnet.

Practically, it is not possible to steal electricity effectively using the neodymium magnet. Every drawing the neodymium magnet closer to the cover of the meter damages its measurement system in such a way that a clear statement of this fact is possible to be proved in a court trial. In accordance with the regulations, a dishonest recipient pays a flat fee far exceeding the value of the stolen energy. Additionally, he or she covers the cost of replacement of the damaged meter, pays high bills for the period, in which the meter indicated overvalued consumption, and bears the costs of a possible lawsuit. The dishonest recipient ultimately bears the costs much higher than the value of illegally input electricity.

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REFERENCES

[1] Saikiran B., Hariharan R., Review of methods of power theft in Power System, *International Journal of Scientific & Engineering Research*, 5 (2014), No. 11, 276-280

[2] Anas M., Javaid N., Mahmood A., Raza S. M., Qasim U., Khan Z. A., Minimizing Electricity Theft using Smart Meters in AMI, *2012 Seventh International Conference on P2P, Parallel, Grid, Cloud and Internet Computing*, (2012), 176-182

[3] Lu Y., Hu J. J., Effect of Neodymium Magnet Field on Operation of Inductive Watt-Hour Meters, *Applied Mechanics and Materials*, 197 (2012), No. 9, 820-824

[4] Pawłowski E., Wpływ pola silnego magnesu neodymowego na pracę indukcyjnego licznika energii elektrycznej, *Pomiary Automatyka Kontrola*, 56 (2010), nr 11, 1259-1261

[5] Billewicz K., Kradzież energii za pomocą magnesu neodymowego i jej wykrywanie, *Przegląd Elektrotechniczny*, 82 (2006), nr 6, 82-85

[6] Kasperczyk B., Ustalanie przyczyn pewnych uszkodzeń indukcyjnych liczników energii elektrycznej, *Wiadomości Elektrotechniczne*, 78 (2010), nr 1, 31-34

[7] PN-EN 62052-11: 2006 Urządzenia do pomiarów energii elektrycznej (prądu przemiennego)-Wymagania ogólne, badania i warunki badań. Część 11: Urządzenia do pomiarów

[8] PN-EN 62053-11: 2006 Urządzenia do pomiarów energii elektrycznej (prądu przemiennego)-Wymagania szczegółowe. Część 11: Liczniki elektromechaniczne energii czynnej (klas 0,5, 1, 2)

[9] PN-EN 50470-1: 2008 Urządzenia do pomiarów energii elektrycznej (prądu przemiennego) Część 1: Wymagania ogólne, badania i warunki badań-Urządzenia do pomiarów (klas A, B, C)

[10] Instrukcja sprawdzania użytkowych liczników energii elektrycznej prądu przemiennego, *Dziennik Urzędowy Miar i Probiernictwa*, (2000), nr 5, 200-207

[11] Rozporządzenie Ministra Gospodarki z dnia 18 grudnia 2006r. w sprawie zasadniczych wymagań dla przyrządów pomiarowych, Dz. U. Nr 3, poz. 27

[12] Rozporządzenie Ministra Gospodarki z dnia 7 stycznia 2008r. w sprawie wymagań, którym powinny odpowiadać liczniki energii elektrycznej czynnej prądu przemiennego oraz szczegółowego zakresu sprawdzeń wykonywanych podczas prawnej kontroli metrologicznej tych przyrządów pomiarowych, Dz. U. Nr 11, poz.63