

An optimizer designed to register ultra fast displacements

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Abstract- In the paper authors present research results of a new simple optimizer used for register of ultra fast displacements of inductive-dynamic drive disk. Presented solution is characterised by very simple construction, high output signal and a relatively good linearity.

I. Introduction

Higher and higher requirements imposed on protective-distributive equipment in the electrical power engineering have caused the development of ultra fast hybrid breakers (Figs 1 and 2) [1]. The tendency and the ultimate aim is to have a short circuit release characterized, first of all, by a very short operation time and repeatability. The period during which in this kind of circuit breaker, the short circuit is completely broken lasts less than 1ms. The construction of HB presented in Figure 1 allows to switch the short circuit off without the arc. Such requirements have resulted in an increase of interest in drives that cause fast movement of contacts. The most important features that a drive should possess are: the ability to reach very high accelerations, the stability of mechanical characteristics and the long-lasting reliability. Among the drives satisfying the above conditions the inductive-dynamic drives (IDD) are most frequently made use of. In the examinations on this type of drives, it is necessary to apply a device of the appropriate quality, which registers any displacement of the IDD disk [2]. A meter used to measure the disk displacement should possess the following features: a small mass of a mobile element, an immunity to the external magnetic field, the lack of friction of the meter elements, resistance on vibration, an endurance to the forces occurring during the displacements and the lack of inertia. Additionally, the meter should be characterized by high dynamics, because it measures the displacements at ultra fast instantaneous accelerations reaching even 50000g. The existing meters, designed to measure displacements, such as: resistance potentiometers, inductive or capacitance transducers, do not satisfy the requirements that would allow these devices to measure such dynamic displacements.

Therefore, there has arisen a necessity to construct an optimizer enabling the registration of element movement, but which at the same time does not have the drawbacks of the traditional meters.

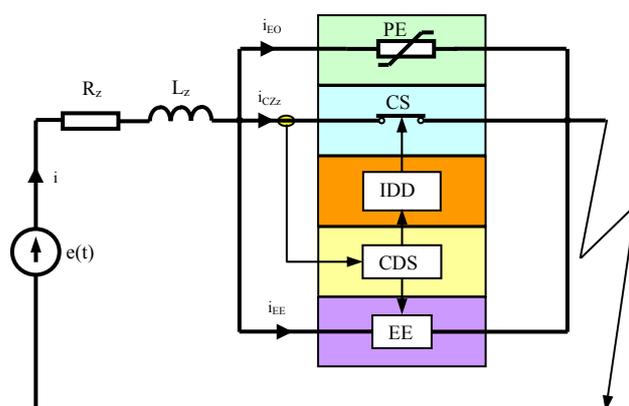


Fig.1 Block diagram of HB in short circuit
 CS– contact segment, IDD - inductive dynamic drive,
 EE – power electronics element, PE– protective element,
 CDS - system of detection of current.

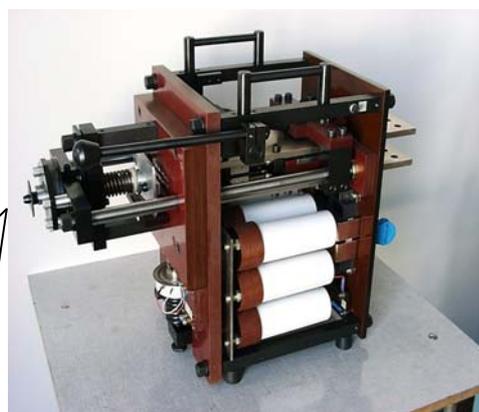


Fig.2 Physical model of ultra rapid HB [1].

1. The construction of an optimeter designed to measure ultra fast displacements

The main measuring element of a meter is a photosensitive element consisting of photoelements connected in parallel, which constitute a “photosensitive ruler”. The “photosensitive ruler” (photoelement) is situated under an aluminum diaphragm in Figure 3. The diaphragm is connected to the IDD disk with the help of a light aluminum pull rod. During the movement of a ring, the displacing diaphragm uncovers the photosensitive element. An increase of the lit surface of the photoelement causes an increase in the output signal on its terminals.



Figure 3. The view of “a photosensitive ruler” with a diaphragm.



Figure 4. The external view of an optimeter.

The meter is equipped with a glass filter made of clouded glass so as to improve the smoothness of visible radiation distribution on the whole surface of this photoelement. The case of the optimeter made of aluminum is covered from the inside with flating black paint so as to prevent possible light reflections and refractions and to minimize the influence of the external light getting out through a slot in the case. The view of the optimeter, in which the diaphragm is connected with the micrometric gauge for calibration, is presented in Figure 4. The measurement system construction which registers the displacement is presented in Figure 5.

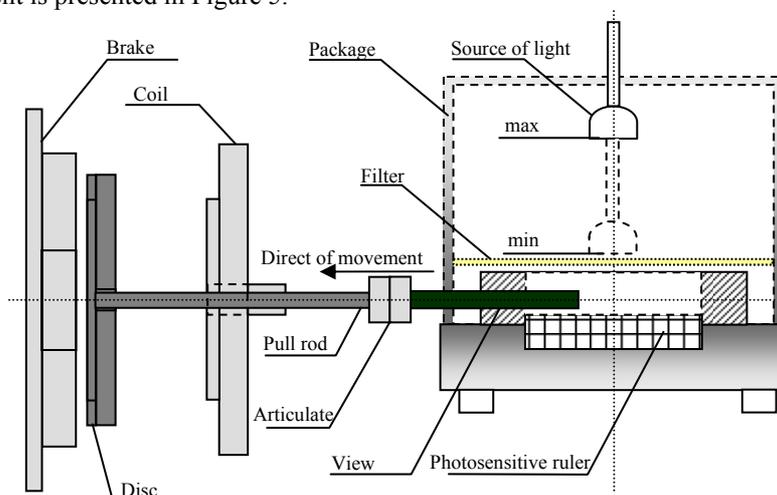


Figure 5. Construction of the measuring system of displacement.

2. Examinations of the static characteristics of the optimeter

The photoelement was examined in two systems: the system of a photo-voltaic cell and the system of a photo-diode supplied from the external voltage source. While carrying out examinations of the optimeter the focus was put on finding the optimal static characteristics. The two most important parameters characterizing the meter, which were analyzed, were: sensitivity and linearity. A sensitivity measured in the examinations was defined as the ratio of the voltage increment to the displacement increment ($\Delta v/\Delta x$). A sensitivity may have a great influence on measurements errors, because the IDD

disk moves within the distances of about 30mm but the fundamental displacement essential for a hybrid breaker to operate does not exceed 5mm.

In the first stage the current-voltage characteristics were measured for a few initial positions of the diaphragm and for different sources of light. This made it possible to determine preliminarily the range of load resistance, which provides the best working conditions with regard to both: linearity and sensitivity of the examined optimizer. Figure 6 presents the exemplary family of the current-voltage characteristics in the system of the photo-voltaic cell, whereas Figure 7 presents them in the system of the photo-diode for the halogen light of the power 3.5 W.

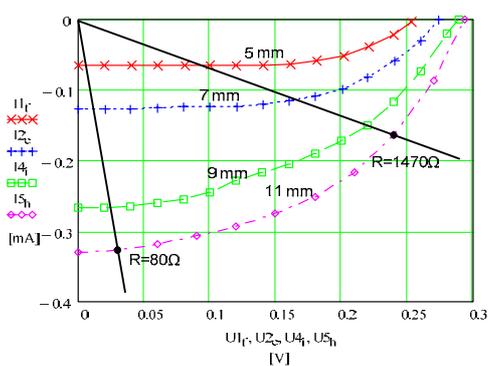


Figure 6. The current-voltage characteristics of the photo-voltaic cell.

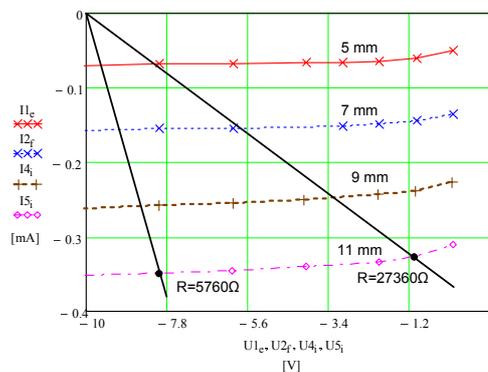


Figure 7. The photo-diode characteristics.

During the examination the influence of a position of the glass filter situated on different heights above the photoelement inside the meter was checked. It was noticed that the distance from the filter to the lamp does not have any significant influence on the characteristics. Additionally, four other light sources lighting the photosensitive element were examined. Among them were: the halogen lamps of the power 50, 20, 3.5W and the fluorescence lamp of the electric power 14W corresponding (according to the manufacturer) to the incandescent lighting of the power 70W.

The measurements range in the system with the photo-voltaic cell can be extended by reducing the load resistance. Exemplary characteristics for the same light source at the different load resistance of the photovoltaic cell system are presented in Figure 8. Figure 9 presents the family of the characteristics of the examined optimizer in the system of the photo-diode for various R for the halogen lamp of the power 3.5W. This time, the characteristics for R=40kΩ obtains highest sensitivity in comparison with the characteristics for the bulb of 50W at the load equal to 500Ω. Simultaneously, this characteristic is characterized in the range up to 8mm by better linearity than in the case of the light of bigger power.

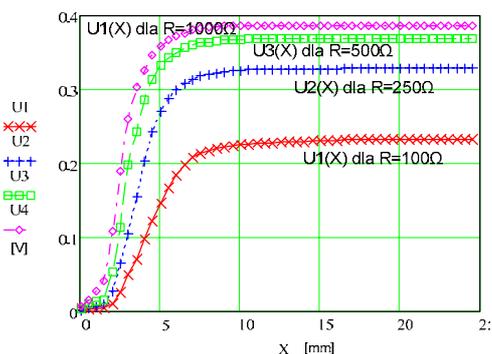


Figure 8. The characteristics of the voltage in the displacement function $U=f(X)$ for the lamp of 20W for $R=var$.

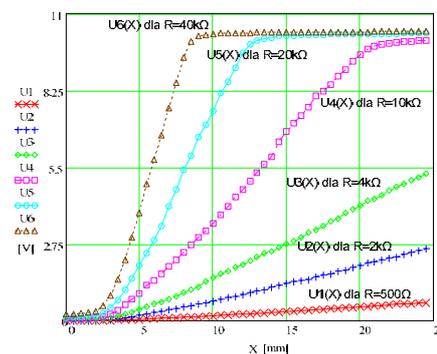


Figure 9. The characteristics of the voltage in the displacement function $U=f(X)$ for the lamp of 3.2W at different loads.

On the basis of the examinations carried out, it was noticed that the operation of the “photo-sensitive element ruler” in the system of the photo-voltaic cell does not guarantee the appropriate measurement range because of the quick saturation of the characteristics with simultaneously smaller sensitivity than

the characteristics in the system of the photo-diode. In both cases the photoelement of the examined meter was characterized by the initial phase of non-sensitivity.

Among the characteristics measured in the photo-diode system the biggest sensitivity was demonstrated by the characteristics for the halogen light source of 50W. Yet, the use of such a powerful bulb caused excessive heating of the whole meter, which additionally affects the measurement results. Therefore, the system with the halogen bulb of the power 3.5W at the load $40k\Omega$ was again selected from all the other light sources, which constituted a compromise between the biggest sensitivity and linearity.

The little power of the bulb ensured the fast thermal stability from the very start. With regard to the phase of non-sensitivity, the part of the selected characteristics in the range from 3 to 8mm was taken into account to register small displacements. If the necessity to register bigger displacements appeared, it would be necessary to reduce the circuit resistance in relation to the required range.

3. Measurements of the ultra fast displacements

The measurement system designed to register displacements of the disk and the coil current is presented in Figure 11 and its physical realisation in Figure 10. The voltage oscillogram obtained from the meter for $R=40k\Omega$ is shown in Figure 12.

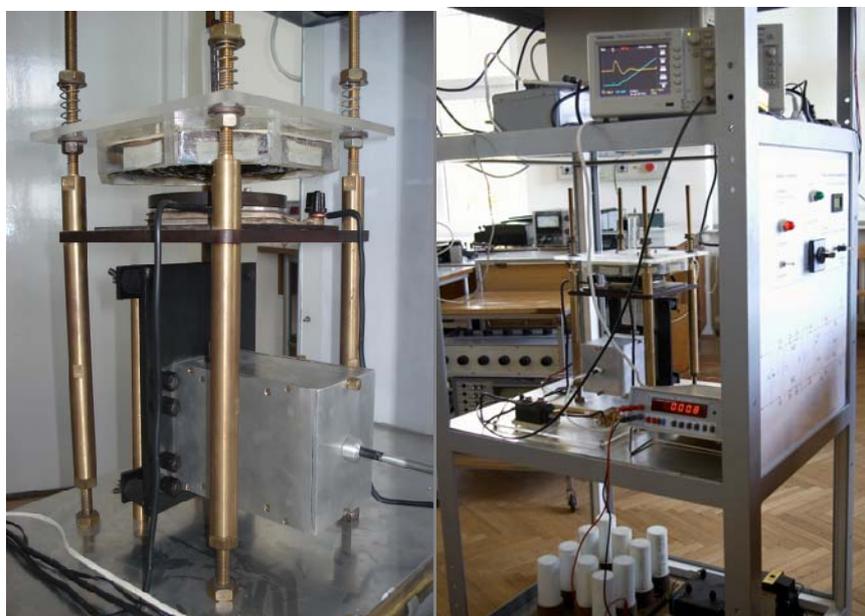


Figure 10. The optimeter connected with IDD and the measuring system.

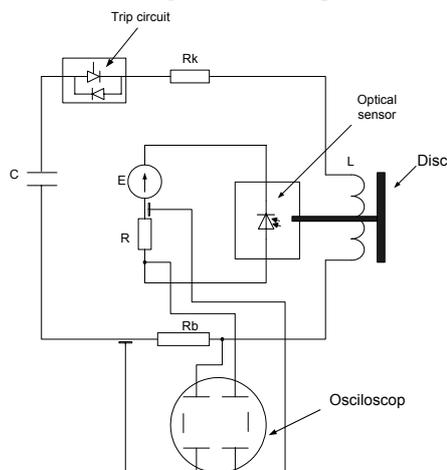


Figure 11. The measurement system to examine the coil current and the disk displacement.

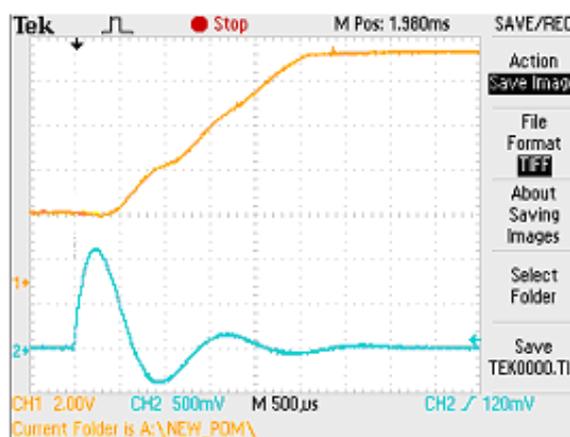


Figure 12. The oscillogram of the disk displacement and the coil current.

Because the whole characteristics of the photoelectric meter is not linear and the output result is the voltage in the time function $U=f(t)$, it is necessary to perform conversion of the characteristics in order to obtain the variation of displacement in the time function $x=f(t)$. The process of changing the scale was performed by the program realized in the Mathcad environment.

In order to check the correctness of the system operation, the characteristic obtained from the examined optimizer was compared with the characteristic of movement obtained from the brand new Megatrom potentiometer (Fig 14). The characteristics registered by the optimizer and potentiometer entered into Mathcad before the conversion are presented in Figures 13 and 15. On the other hand, the comparison of the characteristics of the displacement variation in the time function after the conversion and approximation processing obtained from both the meters is presented in Figure 16.

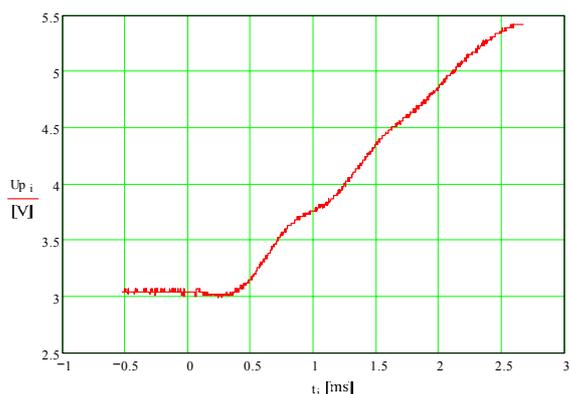


Figure 13 The $U(t)$ characteristic of potentiometer. Figure 14 The Megatrom Company potentiometer.

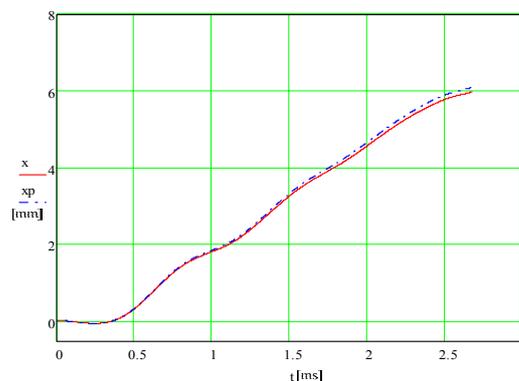
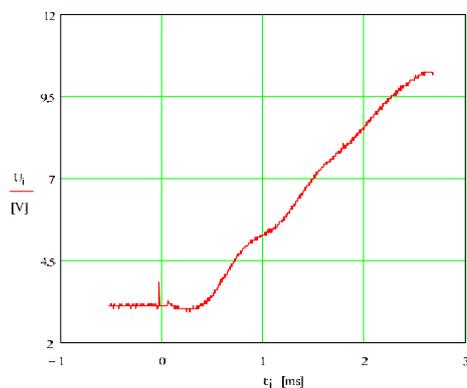


Figure 15. The $U(t)$ characteristic of optimizer.

Figure 16. The comparison of the obtained characteristics from the optimizer and the potentiometer.

The biggest relative difference occurring in the initial phase of movement between the characteristics obtained from the optimizer and the potentiometer did not exceed 3.5%.

II. Conclusions

One has to emphasize that the presented optimizer will be employed to register the much greater dynamic displacement than the one shown in Figure 16. To ensure the correct working of HB, the IDD must displace the contacts within about 100 μ s to a distance of 1mm. Therefore the research into the inductive dynamic drive in range of 5mm of displacement is fully satisfactory.

It seems, therefore, that the presented optimizer allows registering the movement of objects obtaining the displacement variation up to 20mm in a short time, under the short duration pulse force. The range of the maximal speed is more limited because of the mechanical endurance of the drive disk rather than because of the operation frequency of the photoelement, which does not exceed 100MHz. The

optimizer is screened against the influence of the magnetic field generated by the drive coil. Simultaneously, it is characterized by simplicity of the construction, which does not require any additional complex systems [3], [4].

References

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