MODERNIZATION OF A SEISMORECEIVER

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The paper examines in greater details the upgrade of existing, widespread seismoreceivers of magneto-electric type. The method of modernization involves Direct Digital Registration of the relative pendulum motion with respect to seismoreceiver's chassis, which is fixed to the ground. Several theoretic prerequisites have been examined. Three of the most important practical cases for motion detection, velocity and acceleration have also been examined.

The technical implementation has been depicted briefly, employing photo-transforming block featuring an integrated opto-sensor TSL214, as the possibility for substituting it with other opto-sensors has been considered as well. All fundamental technical and operational characteristics of the seismoreceiver have been presented alongside the analysis of potential read-out errors. Greater consideration has been given to one major advantage of this seismoreceiver, namely re-using the magneto-electric transformer's winding as an additional de-emphasizing winding. This leads to obtaining attenuation co-efficients in far greater range. Another positive outcome is the increase of seismoreceiver's operational lifetime, due to the greater compensation to the permanent magnet flux declination. This, also, allows for an automatic detection and correction of the pendulum's "zero-point" dropout.

For the operation in contemporary and field seismic observatories in epicentric zones of catastrophic earthquakes, it is not necessary the seismologic apparatus to have high sensitivity. The reliability, compactness and autonomous work with possibility for telemetric data transmission are of decisive importance.

The subject of this article is to describe the method offered for modernizing of existing and mostly used in the praxis pendulum seismoreceivers of magneto-electrical type. (Apparatus and methods..., 1974; OperatIon and maintenance..., 1980; Operation ..., 1989).

The method (Mardirossian, 2000) offers direct digital registration of the relative motion of the seismographic pendulum towards its chassis firmly fixed on the ground (earth surface).

At small angles θ, as practically the angels of deviation of the pendulum of the seismoreceiver are, and relatively small lengths L_S of the pendulum, differential equation (Savarensky, Kirnos, 1958), representing the relation between the forces acting on the pendulum of the seismoreceiver and the acceleration of the object, has the following form:

$$\ddot{\theta} + 2D_S\dot{\theta} + n_S{}^2\theta = -\frac{\ddot{X}}{L_S}. \tag{1}$$

The equation (1) can be presented in a more simple and easier for the further studies form:

(2) $$\ddot{y}+2D_S\dot{y}+n_S{}^2y=-K_0\ddot{X}\ ,$$

where $Y = K_0\ \theta\ L_S = K_0\ X_C$. Here K_0 is the growth giving the relation between the amplitude of the registration Y and the motion X_C of the swing center of the pendulum against the chassis.

At earthquake situation the earth surface swing can be presented approximately as a sum of several groups of sinusoidal swings having different periods T of the seismic waves. For each of these swings the working-out of the equation (2) is:

(3) $$y=K_0F_SX_{\max}\sin(\omega t+\gamma)\ ,$$

where F is frequency characteristics of the seismoreceiver, showing the relation of the growth K_0 and the period T of the seismic wave:

(4) $$F_S=\frac{1}{\sqrt{\left[1-\left(\frac{T}{T_S}\right)^2\right]^2+4D_S{}^2\left(\frac{T}{T_S}\right)^2}}$$

where: D_S – seismoreceiver's attenuation

T_S – natural period of the seismoreceiver pendulum.

The seismoreceiver phase characteristics Φ_S is:

(5) $$\Phi_S=arctg\frac{2D_S\frac{T}{T_S}}{1-\left(\frac{T}{T_S}\right)^2}$$

The analysis of equations (4) and (5) for three boundary relationships between the natural period T_S of the seismoreceiver pendulum and the periods T of the seismic swings at typical values D_S of the attenuation of the seismoreceiver leads to three important for the praxis boundary cases:

1) $T_S >> T$; $D_S \approx 0{,}45$

Then $F \approx 1$ and $\Phi \approx 0$ where from the equation (4) becomes:

$$Y=K_0X(t)$$

and the seismoreceiver registers without deformation the motion $X(t)$ of the chassis (the earth surface) – *seismograph mode.*

2) $T_{\min} < T_S < T_{\max}$; $D_S >> 1$.

In this mode the swing speed of the earth surface is registered without deformation and the sensibility is

$$K_V = \frac{K_0 T_S}{4\pi D_S}\dot{X},$$ i.e. *velocygraph mode.*

3) $T_S << T$; $D_S \approx 0{,}6$

In this case the earth surface acceleration is registered and the sensibility is

$$K_A = \frac{K_0}{\left(\frac{2\pi}{T_S}\right)^2}$$ and practically without deformations, i.e. *accelerograph* mode.

At the offered method the movement of a point R at distance L_R from the hanging point (swinging axle) of the pendulum M against the sesmoreceiver's chassis is read-out and registered (Fig. 1).

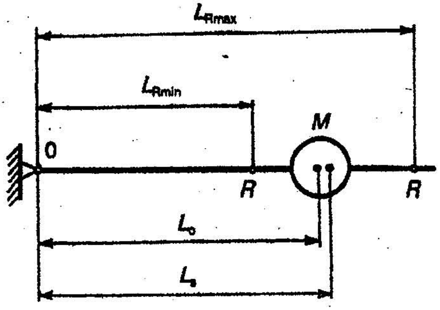

Fig. 1

The following 3 variants are possible:
1) $L_R < L_S$,
2) $L_R = L_S$,
3) $L_R < L_S$.

Having in mind that

(6) $$K_0 = \frac{L_R}{L_S},$$

the simple geometrical considerations show that in the separate three cases the motion X_C of the swing center of the pendulum is registered, respectively: 1) reduced against the real, 2) equal to the real, and 3) increased against the real. The variant choice depends on several factors: seismoreceiver's structural characteristics, the principle of read-out and registering the motion of point R, seismoreceiver's use (for macro - or microseismical studies, for technical purposes, for operation in epicentric zones of catastrophic earthquakes and other).

It is described here briefly the realization of the most expedient, according to us, variant for reading-out and registering my means of phototransformer block (PTB). For this purpose an integrated Texas Instruments opto sensor TSL 214 (Intelligent Opto..., 1995) has been used. The sensor reads-out the transition "dark-light", i.e. the shadow of a proper part of the pendulum's frame or additional fixed special stroke component.

The inner structure of TSL 214 (Fig. 2) is considered to have a connection with a microcomputer or system for digital processing. In this case the standard (Linear Design..., 1992) application for opto-sensor control on the basis of microkontroller which gives the necessary monitoring signals for opto-sensors operation, undertakes the cycle of initial turning on, monitors emitting diode, determines the protocol and the taking out to the output of serial data. The microkontroller is used for gauging of the whole system as well. The diode IRED emits the wavelength λ ≈ 750 nm that provides avoiding of the disturbance of the daylight.

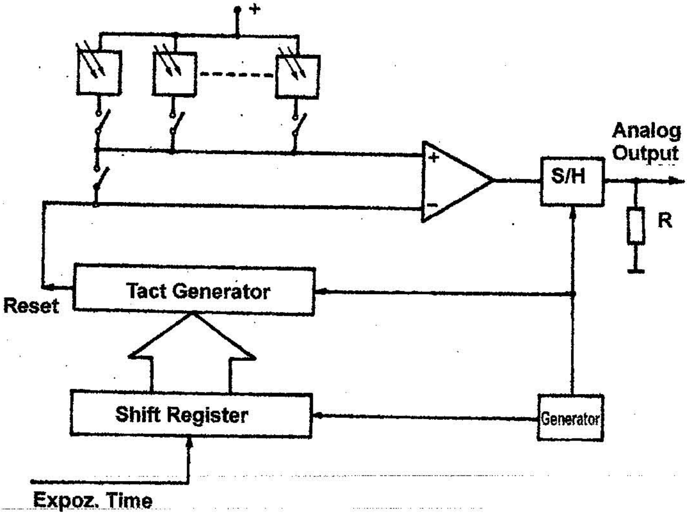

Fig. 2

The used opto-sensor TSL 214 is designed in 14-terminals DIL-case (dimensions 19,3 × 10,7 × 3,5 mm) with window and has 64 components positioned in 0,125 mm distances between the centers (Fig. 3). The geometrical characteristics of the used opto-sensor provides registration in amplitude diapason of 8 mm, i.e. motion amplitude of point $R = \pm 4$ mm that is sufficient because it is the limit for the most seismoreceivers.

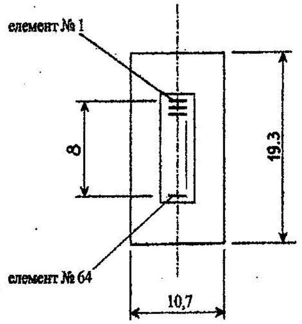

Fig. 3

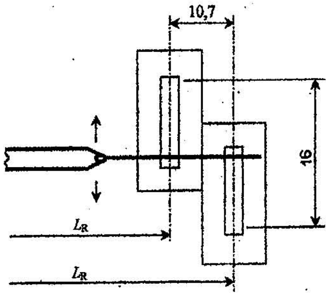

Fig. 4

An experiment has been done using two opto-sensors TSL 214 fixed as shown on Fig. 4. In this case one of the sensors (the upper on the figure reads-out the upward motion of the pendulum, i.e. the downward motion of the earth surface), and the down sensor reads-out – the opposite. The error arising from the fact that the two opto-sensors are fixed on different distances from point O – resp. L^I_R and L^{II}_R ($L^{II}_R - L^I_R = 10$ mm) is very small exceeding some $3 \div 7$ %.

If necessary it is also possible the opto-sensor TSL 215 with twice as many elements and twice as much amplitude to be used. But for this it is necessary a special design of the seismoreceiver.

The technical characteristics of opto-sensors TSL (operational temperature range from –15 °C to + 85 °C and reduced electrical consumption) make them very suitable for work in autonomous mode in no serviced monitoring stations and all kind of natural conditions.

The error arising because the point R moves in arc line and the reading-out is made in a straight line is very small and can be neglected – the value is parts of a %.

The rest free operational winding R_{SG} of magnetoelectrical transformer of the seismoreceiver is used as additional damping winding R_{SD} that provides the possibility of damping D_S in a considerable greater scale. This is very important because in many cases to reach the necessary D_S at seismological registration of powerful earthquakes creates technical and technological problems and is even impossible (Christoskov, Mardirossian, 1979).

At the offered modernized seismoreceiver the operational lifetime is increased because it is possible more reliably to compensate the weakening of the permanent magnet. Due to weakening of the magneto-electrical transducer's magnet, the intensity of the electrical signal is decreased. However this can not be a problem for the modern electronic amplifier. Actually the reason for removing of the seismoreceivers from operation is that if the magnet is weak it is not possible to reach the necessary damping D_S. In this case thanks to the additional damping described above: $D_S = D_{SD} + D_{SG}$ it is possible the wished value D_S^* to be reached.

Because the shadow environment is determined by software, the errors that could be caused by infrared rays are avoided.

Through this method another problem is also solved, i.e. "zero-point" drop-out of the pendulum.

It is obvious that when using seismoreceivers having not special structure but existing seismoreceivers, the distance L_R on which the PTB is fixed can not be longer than the distance L_S of the seismoreceiver (Fig. 1). In the common case it can be accepted: $L_R \approx (1,5 \div 2,0)L_S$. In the used in this particular case FTB with 0,125 mm resolution (Fig. 3) the seismoreceiver will register motion of the ground $X_{min} \approx (0,06 \div 0,08)$ mm. This sensibility can be increased twice through software or through using of an opto-sensor with higher resolution. However this is not necessary since the main use of this seismoreceiver is for operation in epicentric areas.

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