ELECTRICITY METERS USED IN THE RAIL TRACTION

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Abstract: In the paper was comparing the properties of high voltage transducers used in the active traction electric meters.

Keywords: traction electric meters

1 Introduction

Measurements of DC electrical energy consumed by electric locomotives and electric traction seem to be very easy. Until recently, when the electric locomotives drive used DC motors, there have been constant current and voltage waveforms in the traction network. Their values depended on the load of the network in which they appeared. At present modern electric locomotives drivers are based on alternating current motors controlled by electronic power converters. For this reason, the network current and voltage waveforms are deformed. In this case, to measure the electrical energy absorbed by the railway rolling stock, the electric meter calibrated by constant current and voltage signals can not be used. [1,2]

The internal structure of currently produced electric meters assigned for railway traction can be mapped by means of the block diagram shown in Fig. 1.

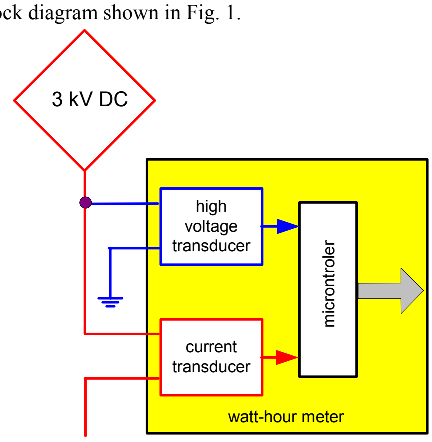

Fig. 1. The structure of the electric traction meter.

In this circuit we can isolate a high voltage measurement transducer, which assigns the voltage value supplying the electric locomotive circuit and the current transducer determining the current flowing through this circuit. In order to measure total energy absorbed by the electric locomotive circuit, i.e. through traction motors, auxiliary and heating circuits, the current transducer must be placed near the positive electric pole of the supply circuit. Output signals of both transducers are supplied into the microcontroller, which inter alia, determines the value of the active energy consumed by the locomotive during its operation.

Depending on the design solution of voltage and current transducers we can distinguish two groups of electronic energy meters.

The first group comprise meters, in the circuit of which, autonomous electronic measurement transducers such as: a high voltage transducer, which measures the traction network voltage and a transducer measuring the locomotive supply current are used. In both circuits galvanic separation isolates the system controller from the high voltage circuit supplying the drive.

The second group could include meters, which meter components presented in Figure 1, are integrated in one housing and are the part of measurement, which by radio or through an optical barrier transfers to the communication part of meter system.

Such DC electric energy meters most often require using multi-resistor voltage dividers. Because of their calibration manner, the meters are not compensated for frequency, which results in additional measurement errors occurring when a deformed waveform of the network voltage can be observed.

The paper compares the properties of voltage transducers used in the active traction electric meters.

2 Current and voltage transducers used in electric traction

Measurement of the traction network voltage can be realized by means of:
- specialized autonomous high-voltage transducers
- resistive dividers

The manufacturer of specialized high voltage transducers designed for railway rolling stock is Swiss company LEM [3]. The company has developed and implemented an electronic device marked DV. The family of these transducers includes high voltage transducers containing isolation amplifier. The transducer of this type is DV 4200/SP3 circuit shown below [4] (Fig. 2).

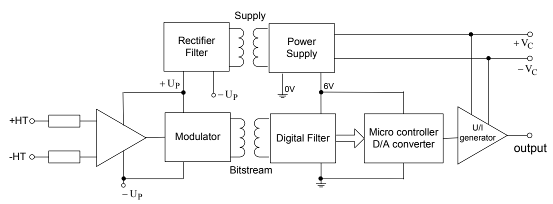

Fig. 2. High voltage measuring transducer with isolation amplifier.

In the transducer shown above the input voltage is supplied through limiting resistors to the input signal conditioner, whose output signal is changed to digital form by means of a sigma - delta modulator with analog-to-digital converter in the input. This signal is sent to the low voltage side of the transducer through a pulse isolating transformer. The sequential appearance in a low voltage circuit can be presented as follows: decoding, digital filtering and digital to analog conversion of the processed signal.

The analysis of catalog data shows that the type of the DV 4200/SP3 transducer is characterized by the frequency band from 0 to 12[kHz], the processing error not exceeding 1% and the nonlinearity error referred to 6 [kV] of value less than 0.03%. The main cause of the top-position restriction of the band frequency transducer operation is sampling frequency of voltage measured by a high primary circuit.

Unipolar form and the traction voltage network may suggest, that the measurement of voltage in the circuit of active electronic energy meter can be done, instead of a DV 4200/SP3 converter, by frequency uncompensated multi section resistive divider, to the output of which, the isolation amplifier (Fig. 3) is connected. The number of resistors R1…RN limiting the value of the measured voltage to the level of the amplifier input voltage depends on acceptable power losses in each resistor. The value of this parameter depends on the design of resistors used in the divider system.

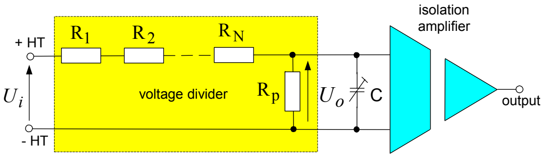

Fig. 3. Isolation amplifier with an input resistive divider.

Taking into consideration limited dimensions of the meter in the divider circuit, a miniature mass metallization resistor or resistors made in SMD technology can be applied. Manufacturers characterize indirectly acceptable power losses in these resistors and in a catalog the acceptable voltage drop do not exceed 50[V]. Therefore when the voltage of traction network equals 3[kV] DC the number of restrictive divider resistors N can not be smaller than 60. The application of such a large number of resistors in the active energy meter forces the manufacturers of active energy traction meters to arrange these resistors in parallel on the edge of the mounting plate, as shown in Fig. 4.

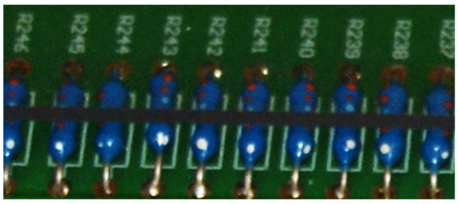

Fig. 4. The arrangement of restrictive resistors on the mounting plate of energy meter.

A divider with restrictive resistors arranged in parallel would impose an additional frequency component to the error of processing power meter, if the voltage of the traction was constant. In fact, the traction network voltage is unipolar, pulse with fast-changing fault and it depends on the locomotive traction motor control and the load state of traction network. [1]. With such a waveform of measured voltage, it is not only the value of applied resistors in this divider, but also parasitic capacity between the resistors which determine the transformer voltage ratio of a divider. The value of these parasitic capacitances depends on the size and shape of the resistors applied in the circuit divider, and a distance and a potential difference between individual resistors. Figure 5 shows the characteristics curve of the dependence of capacity C between adjacent resistors on the mutual distance h between the resistors for the divider shown in Figure 4., where 60 metalized restrictive resistors with resistance value of 330[kΩ] and the acceptable power losses of heat 0.125[W] has been used.

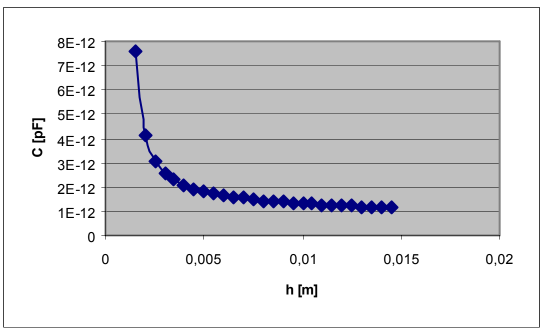

Fig. 5. Characteristics C =f(h) of the divider with metalized resistors.

The above characteristic depicts parasitic capacitances estimated at a few [pF] between divider resistors and metalized resistors can be observed. It suggests that the substitute parasitic capacitance CZ between 60 divider resistors presented in Figure 4 can reach 0.1 [nF].

In order to eliminate the influence of CZ capacitance on divider operation in the input position of insulating amplifier in parallel to measuring resistor, it is necessary to activate an additional capacitor C (Fig. 3). Activating this capacitor will enable to describe the measuring divider by means of a substitute diagram shown in Figure 6.

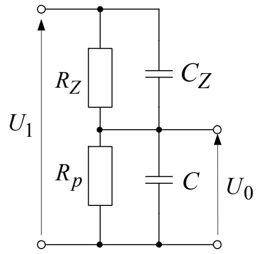

Fig. 6. Substitute diagram of high voltage measuring divider.

In Fig. 6. Rz stands for substitute resistance of restrictive resistors in series R_1 ....R_N a Rp is a measuring resistor (Fig. 3.). It can be proved that transformer voltage ratio can be described by the following expression:

$$k_u(j\omega) = \frac{U_1(j\omega)}{U_0(j\omega)} = 1 + \frac{R_Z}{R_P}\frac{1 + j\omega R_P C}{1 + j\omega R_Z C} \qquad (1)$$

The dependence proves that capacitance C of additional capacitor should be matched so that time-constant of both divider resistors were equal.

$$R_Z C_Z = R_P C \qquad (2)$$

When the value of capacitor capacitance C fulfills the condition (2), transformer voltage ratio of the divider does not depend on frequency and can be described as follows:

$$k_U(j\omega) = \frac{U_1(j\omega)}{U_0(j\omega)} = 1 + \frac{R_Z}{R_P} = 1 + \frac{C}{C_Z} \qquad (3)$$

3 Summary

The paper compares the usability of high voltage transducers applied in active traction electric meters. The first system presented is DV 4200/SP3 transducer manufactured by LEM company. Another one refers to a high-resistance voltage divider collaborating with an insulating amplifier. Both circuits apply galvanic separation so that the electric circuit could be separated from traction voltage. Contrary to LEM transducer, the resistance divider circuit requires an applicable lay-out of the resistors on the mounting plate. Moreover, it requires an accessory frequency compensation which can be done by accommodating an insulating amplifier in the input position, and apart from a measuring resistor, also, an additional capacitor whose value depends on the parasitic capacity between individual resistors. Therefore it is advisable to use high voltage transducers in active energy traction meters in mass production.

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Secondary Paper Section: JB