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ADJUSTABLE THREE – PHASE VOLTAGE AND CURRENT CALIBRATOR

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Abstract − This electronic device will be used to supply measuring circuits during calibration and inspection of measuring transducers of electro-energetic quantities, instruments, electronic protections and electricity meters. It will be very useful as a device to simulate the different ways of loading in electro-energetic network. The incorporated electronics will assure high stability of the set electric quantities, which is especially important for calibration and inspection of digital and etalon instruments.

Keywords: three-phase, galvanic isolation, calibration

1. INTRODUCTION

Three voltages ($100/\sqrt{3}$ V), shifted for 120°, are set on three outputs. This is three-phase wire connection. On other three outputs three currents (1 A or 5 A) are set, which are shifted for 120°. Phase angle between voltage and current is set from 0° to 360° in 15° steps for all three phases symmetrically. The frequency of voltage and current is 50 Hz.

Stability of set voltage, current and phase angle depends on the load impedance connected to output, because of its power consumption (typ. 10 VA per phase) which is delivered from the calibrator. So, it is not quite simple to achieve high stability and narrow error limits of set output quantities. Therefore, direct-coupled output stages principle is applied, which achieves stability of output quantities accompanied by allowable separate phase loading up to 20 VA. Because of the expectation of working in very strong electromagnetically polluted environment, efforts were made to avoid application of sensitive C-MOS components.

The following can be set: AC current; AC voltage; phase between current and voltage; active, reactive and apparent powers; three-phase three-wire and three-phase four-wire systems. Expected calibration class for voltage and current sources is 0,1.

2. THE CALIBRATOR STRUCTURE

The device is composed of reference oscillator, buffer, amplitude regulation stages, phase shifter, monophase to three-phase converter, isolation stages, output stages and power supply unit.

2.1. Oscillator

Reference sinusoidal signal 50 Hz is generated by external AC voltage calibrator (e.g. FLUKE 4800) or by accurate internal oscillator. The construction of internal oscillator is based on square-wave voltage-controlled oscillator (VCO) and sharp low-pass filter.

2.2. Voltage and current settings

Reference signal is brought to the inputs of current and voltage lines which adjust output quantities by its variable gain stages. Each variable gain stage consists of separator (buffer) INA105 and instrumentation amplifier INA110. Very small overall gain temperature coefficient ($TC_A < 20\cdot10^{-6}$ K^{-1} for $A \leq 100$) insures stability of set output electrical quantities. tables.

2.3. Phase settings and monophase to three-phase conversion

The phase-shift regulation between three-phase voltage and current is achieved by adjustable phase shifter which is implanted into the voltage line. Except this specifically phase shifter, the voltage and current lines are identical.

Three-phase voltage, which is led in output stage, is drawn from dual two-stage phase-shifter. Each stage, consists of buffer INA105 and precision operational amplifier OPA27 (BB), produces fixed phase shift of 120°. With voltage gain of 1, the gain temperature coefficient is minimised.

2.4. Galvanic isolation and output stages

Output stage of calibrator consists of three independent voltage and current sources. Each source represents “Assembled Operational Amplifier” (AOA), which have harmonic distortion, input offset and open-loop gain similar (identical) to the basic operational amplifier. “Assembled Operational Amplifier” consists of operational amplifier, two low-voltage stabiliser which serves as operational amplifier supply, phase splitter, current limiter, power amplifier and feedback network.

The voltage source consists of “Assembled Operational Amplifier” which is based on the operational amplifier and supplied with stabilised voltage ± 110 V_{DC}. The parameters of the used operational amplifier OP77 (gain $A_{VO} > 120$ dB, input offset voltage $V_{OS} < 30$ µV, temperature coefficient $TCV_{OS} < 0{,}3$ µV/ºC , and noise voltage density ≈ 10 nV/$\sqrt{Hz}$) guarantee the minimisation of their negative influence. The signal is applied to the noninverting input and a portion of the input signal returns to the inverting input. Open loop gain of $A_{V0} \approx 10^7$ decreases to $A_{VN} = 10$ in noninverting circuit and it is determinated by the R_2/R_1 resistance ratio of output divider (Fig. 1). The temperature coefficient of R_1 and R_2 (TC ≈ 10^{-5} K^{-1}) determines gain error limits.

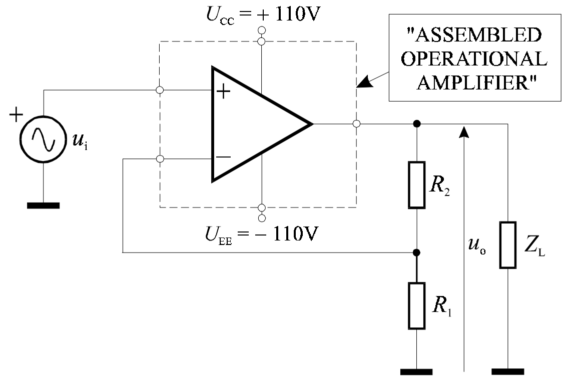

Fig. 1. The voltage source

The current source 1A/5A consists of "Assembled Operational Amplifier" based on OP77 operational amplifier in transconductance amplifier circuit (Fig. 2). The circuit is supplied with stabilised voltage ± 28 V_{DC} and ± 9 V_{DC} respectively. Transconductance is expressed by:

$$G_M = \frac{i_o}{u_i} = \frac{i_{R_{SE}}}{u_{R_{SE}}} = \frac{1}{R_{SE}} \tag{1}$$

R_{SE} is precision shunt with TC ≈ 10^{-5} K^{-1} which determines transconductance of G_M = 1 A/V and 5 A/V respectively.

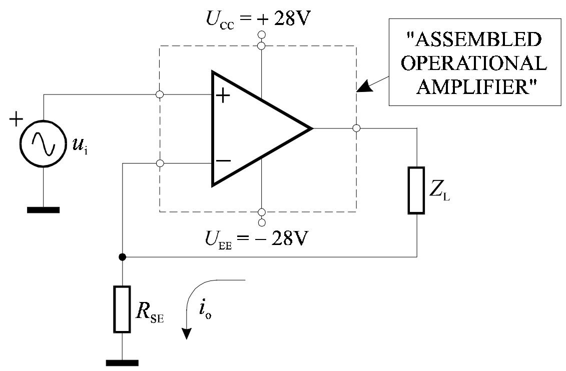

Fig. 2. The current source

The purpose of current-limit circuits in both voltage and current sources is to control power dissipation of output stage without disturbing signals nearing the limit.

The direct coupling principle of loads and output stages dictates the need for galvanic insulation of drivers. This is realised by optocouplers-isolation amplifiers HCPL 7800A (HP) which utilise sigma-delta (Σ-Δ) analogue-to-digital converter and differential circuit topology.

They meet rigorous criteria for voltage gain drift vs. temperature ($\Delta A_V / \Delta T = \pm 3 \cdot 10^{-5}$ K^{-1}) with low harmonic and phase distortion (THD ≤ 0,01 %; $\theta \leq 10^{-3}$ rad at 50 Hz). It is important to mention that the power supply must be galvanically insulated for each output stage.

In case of voltage source, the stability of output voltage depends on temperature coefficient of resistors in output divider; it is favourable if they are equal. Stability of current source is determined by temperature coefficient of shunt, which power dissipation is not negligible and claims greater attention.

In experimentally testing without thermostating, with various output powers (from 0 to 20 VA) and loads with cosφ between 0,05 (close to absolute reactive load) and 1,00 (active load), gain error limits of voltage source were $G_{Av} \leq$ ± 0,03 % (± 300 ppm) and of current source were $G_{Ai} \leq$ ± 0,1 %. In both cases, total harmonic distortion was below 0,05 %. With thermostated circuits we expect much better results.

3. CONCLUSION

The realisation of the device described above is not finished yet. The first function tests were finished a few days before the deadline of this manuscript. The measurement of their metrological characteristic will be made and published in the near future.

The designed device will enable the comparison of the results, which will be achieved using different methods or different systems for testing dynamic parameters of power transducers and energy meters. Thus it will be possible to assess its real precision. Unlike commercial produced calibrators, in our device the full galvanic insulation of the each phase is used to minimise the disturbances. In addition, the whole device will be thermostated to obtain high stability of its parameters.

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