ISSN:2321-1156

International Journal of Innovative Research in Technology & Science(IJIRTS)

ELECTROMECHANICAL PHASE MULTI-STABLE ELEMENT

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Abstract

An electromechanical phase multi-stable element (EPMSE) is implemented by combining the electromagnetic system with an electronic device. Actuator components of continuous operating mode (AC or DC motors) can be used as actuator element. By embedding an electronic circuit one can create electric balance state (which is practically difficult to get by using only an actuator). An element is regulated by the control system of control signals in the form of number-impulse or digital code transformed into discrete angular movements. The paper provides a block diagram, multi-hump characteristic, experimental characteristics received in the course of the unit being under operation. Proposals are given on how to reduce the element dimension and weight. Application areas for EPMSE are proposed.

Introduction

Design and development of the elements and systems of process control, in particular of actuators of discrete action with multiple stable states (electromechanical multi-stable components) is of particular interest nowadays in view of the ever intensifying scientific-technological progress and largely driven by the need to boost production efficiency by means of widespread implementation of fundamentally new process control systems.

The widespread use of electromechanical multi-stable elements helps reduce the quantity of the equipment required for processing the existing data and improve the degree of reliability of control systems.

In control systems, the electromechanical multi-stable control elements are traditionally built on the basis of the electromagnetic systems combined with mechanical or electronic counting units. Electromechanical multi-stable elements with mechanical counting units are characterized by low speed due to wear and tear of mechanical parts, sufficiently high noise degree while at operation, the dependence of digit apartments and performance on design configuration of mechanical parts.

Main

Elements with electronic counting units are known for higher performance (speed), reliability, the simplicity of circuitry, serial fitness, and higher digit compartment capacity.

In view of the above mentioned, research and development of innovative, flexible, simple, high-performance and cost-effective elements with electronic counting units is of particular concern.

Stepper motors, stepping relays and various combinations of the mechanical devices with electrical drives are in this range [1, 2, ...].

B.P. Sigorski, L.S.Sitnikov, L.L. Utyakov, M.A. Rakov and A. Abdukayumov elaborated the theorem of multi-stable elements, the digit-value of which is obtained merely by modifying electronic circuits. Series of multi-stable electromechanical elements have been developed based on this principle [3] including electromechanical phase multi-stable elements, frequency multi-stable elements of linear motion [4,5,6, ...].

All electro-mechanical multi-stable elements are implemented based on the principle of basis proposed by M.A. Rakov. When using the principle of basis, operating data of elements are set from outside, while the element has only to simulate the data. Meanwhile, all elements of the system are connected to the common source of power, that generates additional, the so called basis voltages. Basis voltages represent the grid of voltage levels and time intervals specified in the maximum range,- i.e. the period for the basis functions.

It's possible to build K^k different series of functional transformations in the basis formed by k discrete voltage levels by parting the period on K time intervals.

Electromechanical phase multi-stable element (EPMSE), that translates number of impulses or digital code into discrete angular displacement, is implemented by means of combining the electromagnetic system with an electronic device [7,8,9].

There is a schematic diagram of EPMSE on Fig. 1 with 16 stable states, where the PR stands for "phase rotator", SA1, SA2 –"selective amplifiers", IS1, IS2 – "impulse shapers", PD – "phase detector", FLF – "filter of low frequencies", DCA – "DC amplifier", DCM – "DC motor".

ISSN:2321-1156

International Journal of Innovative Research in Technology & Science(IJIRTS)

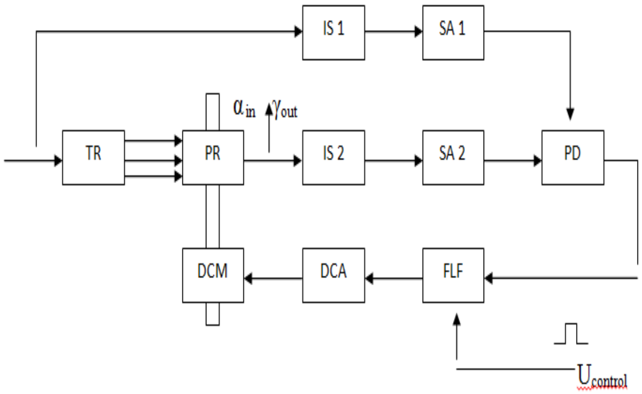

Figure 1. Schematic diagram of EPMSE

The element operates as follows. Phase voltage of the output winding of PR with frequency equal to the frequency of the supply voltage, varies in proportion to angle of rotation of the rotor. From output of the diode bridge, pulsing voltage of double frequency (i.e. 100Hz), enters.

This voltage with phase shift is applied to the input of IS2 and unipolar pulses required for gaining multi-hump characteristics (Fig. 2) appear on their output.

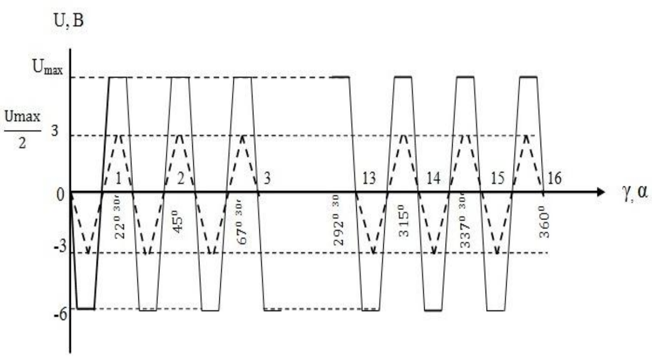

Fig.2. Static input-output characteristic
U_{max}- amplitude of rectangular impulses
$\frac{Umax}{2}$–max value of the constant component without filter (the dotted line).

Unipolar pulses are selected on term of $\sin\frac{n*\delta}{2} = 1$, and are applied to the input of SA1 configured to n- harmonics (in our case n = 8, δ = 1,25ms)

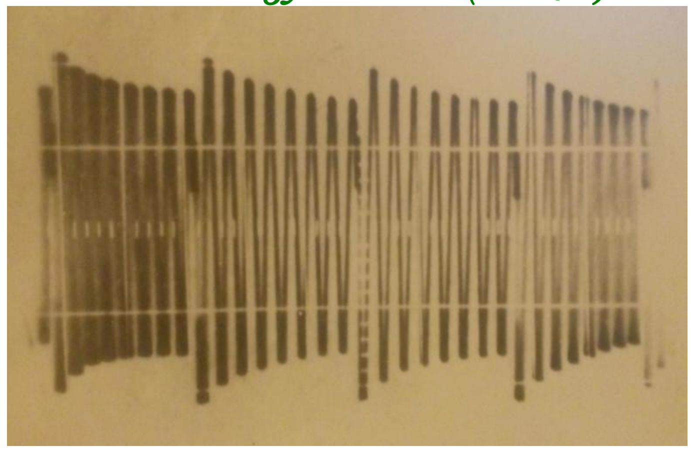

Fig.3. Experimental shotwave form

There is an experimental shot waveform of voltage on the output of the selective amplifier on Figure 3.

The number of harmonics sets out the number of stable states of the element. The phase detector from the output of which and through the FLF, DC voltage is applied to the DCM, ensures feedback loop contact of the quadripole with multi-hump characteristic.

Additional IS1 and SA1 ensure reference voltage to PD. One complete revolution of the rotor of the PR leads to change in the angle of phase shift between output pulses of shapers to 2π. Meanwhile, the phase of n-harmonics changes to 2πn, resulting in the constant output voltage of the PD adopting maximum and minimum values n-times. At 0, (2π),$\frac{\pi}{n}$, $\frac{2\pi}{n}$,….,$\frac{2n-1}{n}\pi$ the constant voltage takes zero value, which define points of stable equilibrium.

Shifting element from one stable state to another control mode is carried out by generating control impulse. When control impulse is given to FLF, constant voltage is applied to the winding of the engine control, which induces rotation of its shaft in one direction or the other depending on polarity of the control pulse, which, in turn, shifts the shaft of PR to the required stable state. In such a state, the element is fixed for as long as desired.

Owing to discrete nature of motion of the system, a program written by natural pulses is used, where shift distances are determined by simple number of pulses, i.e. each pulse has a fixed value in units of movement.

To compile the program, parameters of the control pulses (Fig. 4) have been experimentally studied for n = 16,8,4,2,1 stable states in 360˚, i.e. at times when intervals between stable states account for 22˚ 30', 45˚, 180˚, 360˚. Optimal values of control pulse are selected based on conditions of:

$t_{uopt.} = \alpha/n_{average}$ where, $n_{average} = n_{max} + n_{min}/2$

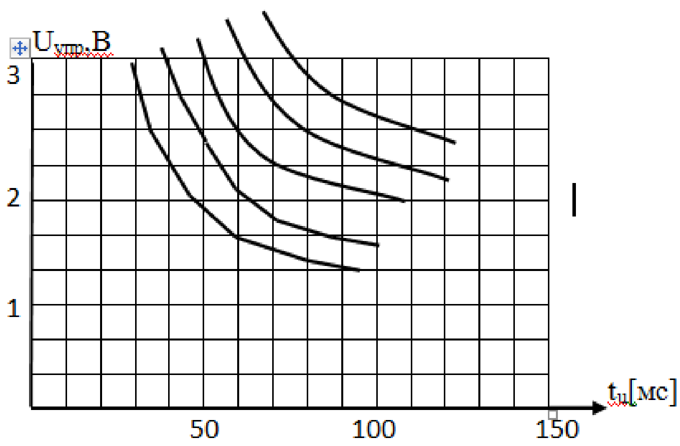

Fig.4.Parameters of control pulses

To reduce dimensions and weight of EPMSE:

1. One can replace three-phase transformer that feeds the phase rotator (resolver) by 3 two-section phase rotating chains of type "*R- parallel*" or type "*C-parallel*" (Fig. 5) which transform single-phase input voltage to three-phase input voltage.

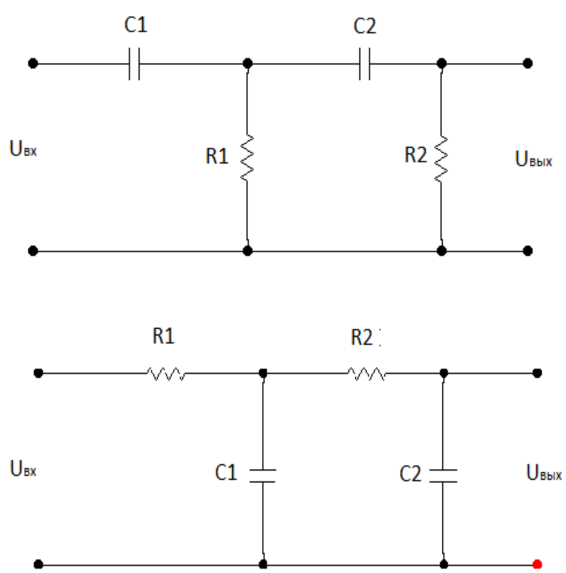

Fig.5. Phase-rotating chains

However, in case of phase rotating chain with identical sections each successive section tends to exert shunting action on a previous one.

To reduce the shunting effect of sections and decrease attenuation, progressive chains diagram can be implemented in the phase-rotating circuit:

i.e. $R2=m*R1$; $R3=m^2R1$

$C2= C1/m$; $C3=C1/m^2$

Usually, the value of m does not exceed 4 ÷ 5.

Toreduce the dimensions of the phase rotating transformer, one can implement the improved option of "*single-phase voltage transformer-to-three-phase transformers*" on a single chip [10].

2. One can combine electromechanical element-resolver-engine in a single casing.

3. All electronic circuitry shall be replaced by integrated circuits.

EPMSEwas practically implemented in the system of process control of low-speed drilling machine, where it was used as an actuator for moving platform in polar coordinates. EPMSE was also implemented in the system of control of cotton gin. It is used for transfer of information to the control unit about the state of the grizzly shaft that feeds raw cotton to the gin chamber during initial processing.

EPMSE can be widely applied in systems designed for transforming output signal to the turning angle of the crankshaft. The unit can be applied in digital process control systems of machine tools as an actuator for moving platform in polar coordinates.

EPMSE operates as an integrator of *number - impulse* input signal. Therefore, any physical variable signal after being converted to number of pulses could algebraically be summed

Acknowledgments

The author is thankful to IJIRTS Journal for the support to develop this document.

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Biographies

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