ASPECTS OF CREATION OF ASYNCHRONOUS OSCILLATING ELECTRIC DRIVES

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Abstract. Squirrel-cage asynchronous motor connected to single-phase sinusoidal voltage is researched. Shown, that connecting the stator windings in a certain sequence of half-period positives and negative voltage, a motor rotor is rotated, but three times slower than in the three-phase mode. Using the connecting sequence of half-period voltage to stator windings, motor can work in the oscillating mode. It is tested experimentally. Characteristics of stator winding current *I* and active power *P* depending on voltage *U* of motor in rotation mode for no-load and broken rotor cases are taken off.

Key words: asynchronous motor, modes, operating switch, voltage, current.

Introduction

The oscillating electric drive is widely applied in mechanisms of vibrotransporting, of vibrosorting, of polishing machine tools, etc. In these devices rotary movement of the electric motor will be transformed in oscillatory by means of various cinematic parts.

The task for reduction of metal consumption, weight and size parameters, simplification of operating system is to search for the ways to obtain oscillations without the mechanical running gears. In practice for providing oscillation the different types of motors (asynchronous, synchronous, step and direct current motors) and operating methods are used [1].

Principle of operation

An object of our researches is three-phase squirrel-cage asynchronous motor in oscillating mode, which is connected to single-phase voltage.

In 80th last century in RPI (now RTU) the staff of the Electric Drive department patented the operating method of three-phase asynchronous motor, which is connected to single-phase sinusoidal supply voltage [2]. The positive or negative half-periods of the voltage are connected to the stator phase windings of motor, through the semiconductor switch in a certain sequence. This sequence is shown in Fig. 1.

Starting with the positive half-period of voltage, motor is connected to A phase winding, starting with the negative half-period of the voltage – switched to B phase winding, with the next positive half-period – C phase winding. The following negative, positive and negative voltages are connected correspondently A, B and C phase windings. Thus one cycle is completed during 3 voltage periods. Further the same cycles are completed. In such mode the currents flowing in the stator windings create a pulsating rotation magnetic field with the rotor windings link.

During each half-period direction of the magnetic flux perpendicular plane of the proper winding and a flux value changes by sinusoidal law. In the next half-period a flux value again changes after a sinusoidal law, but its direction changes for 60º. During the time of six half-periods (3 periods) the direction of the magnetic flux executes a complete turn for 360º. This rotation field generated voltage in the rotor windings. Interaction of rotor currents and magnetic flux is created by an electromagnetic torque, which rotates a rotor. In this mode the magnetic field rotates three times slower than a motor connected to three-phase voltage. Correspondently three times slower a rotor rotates also.

Experiments are executed with squirrel-cage asynchronous motor with two magnetic pole pairs, for three-phase alternating voltage (frequency is 50 Hz) rotation frequency no-load mode is 1500 min^{-1}, but connecting single-phase voltage – 500 min^{-1}.

The considered operating method can be modified so that the rotor of motor was not revolved, but operated in the oscillating mode [3]. For the above-described operating method a sequence of half-period voltage was: **A – B` – C – A` – B – C`**. Here "`" means, that according to winding the negative half-period of voltage is connected. During the time of three periods the direction of the magnetic flux changes for 360 electric degrees, but a rotor turns for 180º.

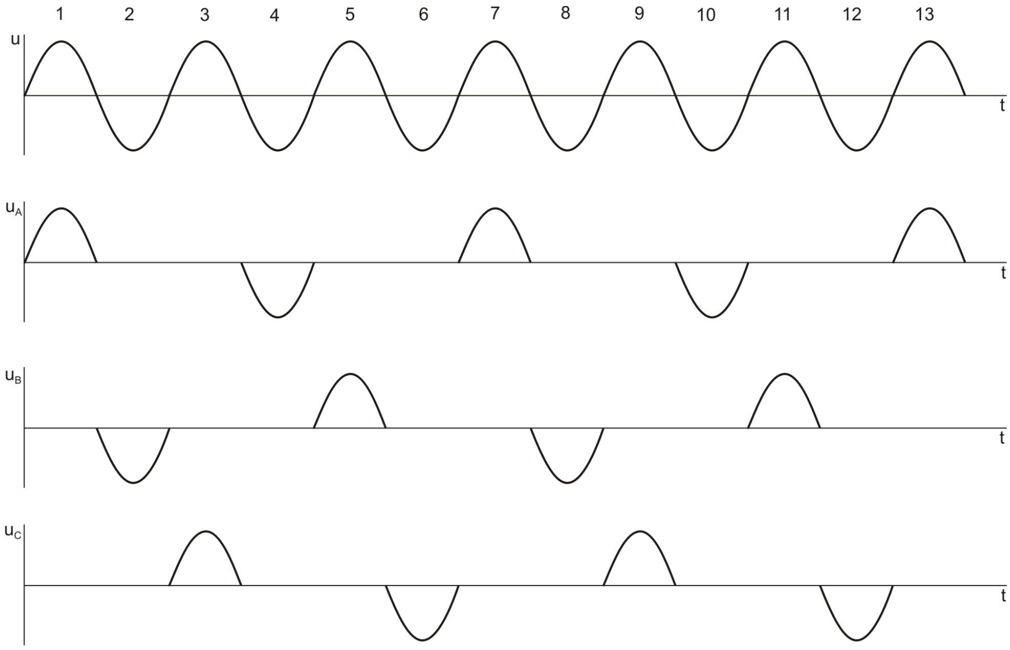

Fig. 1. **The voltages of stator windings distribution**

The followings three periods (6 half-periods) a voltage connects sequence: **A – C` – B – A` – C – B`**, and the magnetic field and also rotor rotate in the opposite direction. During the time of six voltage periods a rotor completes one oscillation or 50/6 = 8.167 oscillations per second, but a turn angle – 180º each side. It can change frequency of oscillations, changing a rotor turn angle. Decreasing the angle of turn, frequency of oscillation increases and the period of oscillation diminishes. Increasing the angle of turn, frequency of oscillation diminishes and increases the period. Certainly, the period of oscillation can be regulated also changing frequency of the connected voltage.

Return to the motor rotation mode analysis. Asynchronous motor one stator winding input voltage $u = U_m\sin\omega t = U_m\sin\alpha$ is described with a differential equation:

$$U_m\sin\alpha = iR + \omega L\,di/d\alpha. \tag{1}$$

The solution of which, if the voltage is connected at the beginning of half-period, is the following:

$$i = \frac{U_m}{\varpi L}\frac{1}{1+k^2}\left(e^{-k\alpha} - \cos\alpha + k\sin\alpha\right). \tag{2}$$

where i – instantaneous value of current in stator winding, A;
u – instantaneous value of input sinusoidal voltage, V;
L – inductance of asynchronous motor single-phase winding to a no-rotating rotor and given voltagefrequency, H;
R – active resistance of asynchronous motor stator phase, Ω;
$\omega = 2\pi f$ – angular frequency of input network, rad/s;
$k = R/\omega L$ – coefficient.

Voltage diminishing to zero value and changing polarity, a current continues to flow. At certain angle α_N winding current does not change, equation can be expressed as:

$$e^{-k\alpha} - \cos\alpha + k\sin\alpha = 0. \quad (3\}$$

Active power of one stator winding in one pulse period time can be determined as:

$$P = \frac{1}{T}\int_0^T uidt \tag{4}$$

where T – pulse period, s.

The stator winding output electromagnetic power in one time differs for a size $\Delta P_{CU1} = i^2$ R. To the given loading power during one time period is an unchanging size.

Experimental device and connection scheme

The three-phase squirrel-cage asynchronous motor with two magnetic pole pairs is used in an experiment. Motor parameters: 0.55 kW, 220/380 V, 2.9/ 1.7 A, 1360 min^{-1}., cosφ = 0.71, η=71 %. Motor is connected to the electrical grid with 220 V through an autotransformer, that can regulate voltage values. The stator windings are connected in a star. Each winding is connected to voltage sources with opposite-parallel direction concluded optical thyristors. An operating scheme provides possibility in a certain sequence to give control impulses to the thyristors, connecting the proper stator winding positive or the negative half-period voltage.

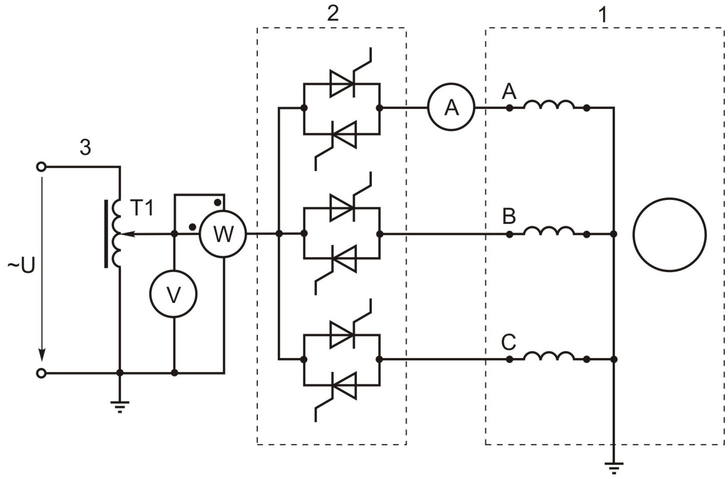

Fig. 2. **Asynchronous motor connection scheme:** 1 – asynchronous motor, 2 – semiconductor switch blok, 3 – autotransformer

With this scheme it can explore motor action both in the rotary mode and in various oscillation modes, varying microcontroller program. Semiconductor operating switch scheme is not represented in Fig. 2. For measuring voltage a voltmeter is connected in a scheme, for stator winding current – amperemeter and for consumption power – wattmeter.

Experimental results

The experiment proved, that the motor operates both rotating and in the oscillating modes. Three various oscillating modes were observed, but not in details. The research of rotation mode was started only.

Table 1

Measuring results of voltage, current and power for no-load and braked rotor modes

No-load mode			**Braked rotor**		
U, V	*I*, A	*P*, W	*U*, V	*I*, A	*P*, W
29.4	0.425	12.5	29.9	0.55	25.0
40.1	0.600	25.0	40.0	0.75	50.0
50.4	0.775	45.0	50.1	0.90	75.0
60.0	0.995	65.0	60.3	1.10	115.0
70.1	1.175	105.0	70.0	1.30	155.0
80.5	1.450	150.0	79.2	1.45	195.0
100.4	2.000	290.0	99.8	1.85	320.0
119.7	2.475	460.0	120.3	2.25	470.0
139.8	2.950	670.0	140.0	2.55	640.0

The motor no-load mode is experimentally explored with various input voltages, measuring a current in the stator winding *I* and active power *P*. Results are given in Table 1. Motor rotation frequency for all voltage values is about 497 min^{-1}, magnetic field rotation frequency is 500 min^{-1}. Promoting input voltage *U*, both a current *I* and power *P* increases. Such measurings are done also for a motor with broken rotor. Results are shown in Table 1.

Special there is that in the no-load mode and in the mode with a broken rotor the currents in stator winding are almost equal. If voltage *U* exceeds value 90 V, a winding current in broken rotor case even less than in no-load mode. Equal situation exists also with the consumption active power *P*. Oscillogram of input voltage *U* and stator winding A-phase current *I* is shown in Fig. 3.

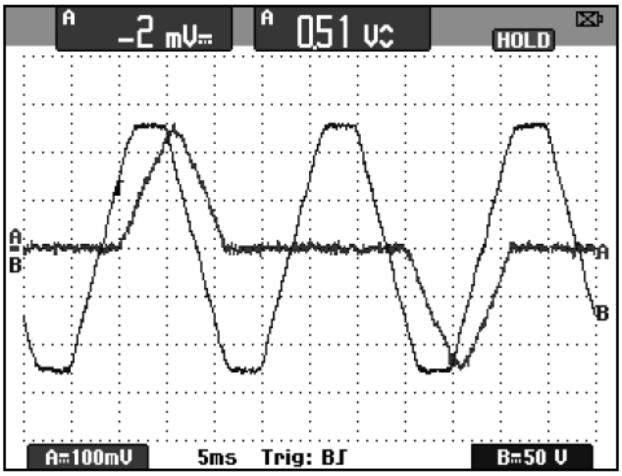

Fig. 3. **Oscillogram of stator winding current and voltage:**
A – current curve, B – voltage curve

The experiment proved, that the motor can be started up, if one stator winding is not connected to voltage. As it is generally known a starting up of a motor without one phase is impossible. Continuing eksperiments assumes to take off mechanical curves $n = f(M)$ and curves $I = f(M)$ at different voltage values.

Conclusion

1. The presented method gives the possibility to initiate an asynchronous motor with cage rotor, connected to single-phase voltage, both in rotation and in oscillating modes.
2. The motor is connected to a decreased, instead of rated voltage.
3. In long-term plans the motors can be used in the oscillating modes. Without changing a power and operating schemes, but changing the program of microcontroller only, it is possible to change the rotor amplitude and frequency of oscillations.

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