Features of an induction motor design taking into account the possible operation in the mode of electrical asymmetry of the windings resistances

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Abstract. The paper examines the operation of large high-voltage induction motors used as an electric drive of critical installations in enterprises with a continuous production cycle. The theoretical foundations of the appearance of a dip in the mechanical characteristic of an induction motor in the mode of winding resistances asymmetry are considered. The developed power supply device for an induction motor with torque dip compensation at electrical asymmetry of phase windings appears is presented. The necessity of introducing a service factor is formulated to take into account the decrease in the total level of the electromagnetic torque in such operating modes, which is carried out at the stage of the motor design beginning.

1. Introduction

According to statistics only 20% of electric motors work without accidents before being taken out for overhaul, in other cases they deal with early occurrence of malfunctions during operation. In the overwhelming majority of cases the cause of failure of induction motors is damage to the windings (85-90%) which in turn are most often caused by turn-to-turn faults (93%).

The resulting defects often become the cause of various kinds of asymmetries in the electric and magnetic circuits of electric motors. Along with a change in the magnitude and shape of the windings currents as well as the appearance of motor vibration, a significant consequence of asymmetry is a decrease in the motor electromagnetic torque magnitude.

The protection existing today is aimed at preserving the electromechanical system as a whole and in most cases is reduced only to an emergency shutdown of the electric machine in the event that the phase currents exceed the permissible level. However, in some industries (metallurgy, cement, chemical industry) with a continuous production cycle this may be highly undesirable for economic or safety reasons. An example is clinker kilns at cement plants where stoppages in the work process are not allowed by the technological process and lead to significant material costs.

Methods using standby motors for critical installations in relation to high-voltage high-power motors have a number of disadvantages: high cost of implementation and maintenance, technical difficulties in the organization, the need for large production areas.

Consequently, it becomes necessary to implement in the operating equipment the temporary elimination of the asymmetry negative effects, in particular, the reduction of the electromagnetic
torque, which will make it possible to complete the production cycle and the subsequent withdrawal of the equipment for repair.

2. Theoretical foundation of torque dip presence

According to the theory of electromechanics, the source of the mechanical characteristic dip of an induction motor with asymmetry in the rotor circuit is a parasitic asynchronous moment that occurs when the reverse sequence rotor magnetic flux acts on the stator circuit [1].

![Figure 1. Torque curves of forward and reverse sequences with unbalanced rotor](image)

To minimize this parasitic torque, weakening of the negative sequence current in the rotor or stator is necessary. Minimization of the negative sequence current in the stator is possible by introducing a counter EMF into the stator circuit to compensate for the above induced EMF negative sequence, or by increasing the circuit resistance. Thus, the following methods of weakening the parasitic asynchronous torque can be distinguished by: the introduction of a back-EMF into the stator circuit, the introduction of resistances into the stator circuit, as well as the use of a three-phase current source for forced setting of the stator phase current.

A choice was made in favor of the forced setting of currents in the stator windings having highlighted the advantages and disadvantages of the listed methods. This method formed the basis for the developed and patented device for electromagnetic torque dip compensating.

3. Torque dip compensation device

Figure 2 shows the block diagram of the developed induction motor power supply device with compensation of mechanical characteristic dip.
Figure 2. Block diagram of an induction motor power supply device with compensation of mechanical characteristic dip

The device works as follows: when the supply voltage is applied, the master oscillator 10 generates sinusoidal symmetrical voltage levels, multiplied by a factor inversely proportional to the average value of the stator phase amplitudes and limited by the set maximum starting current. The products of voltages by this coefficient are fed to adders 4, 5, 6, at the outputs of which the difference components of the currents of the set and the currents actually flowing through the phases of the stator of the induction motor 20 are formed. This difference component controls the bridge inverters 21, 22, 23 based on PWM - the appearance of a positive current error signal leads to an increase in the pulse duration in the PWM period due to which the average voltage value at the output of the inverters 21, 22, 23 increases, and vice versa - negative the current mismatch signal reduces the pulse duration in the period which leads to a decrease in the average voltage at the output of the inverters 21, 22, 23.

With large slips of the rotor and maintaining the rated current in the stator of the motor 20 the machine torque is small and increases only when the slip is close to the nominal. The stator phase voltages at large slip is also low. To compensate for the starting torque in the proposed device a correction circuit is provided consisting of an average amplitude formation unit 13, a nonlinear conversion unit 12 and analog voltage multipliers 7, 8, 9. This correction circuit increased the level of induction motor stator phase currents at low stator phase voltages by multiplying currents generated by the master generator 10 currents per coefficient inversely proportional to the amplitude voltages of the stator phases [2].

For example, the results of modeling the device-motor system with asymmetry of electrical resistances in the rotor circuit are given by figure 3-6.
Figure 3. Stator phase currents at rotor asymmetry modes and torque dip compensating by developed device

Figure 4. Rotor phase currents at rotor asymmetry modes and torque dip compensating by developed device
Figure 5. Rotor angular frequency and electromagnetic torque at rotor asymmetry modes and torque dip compensating by developed device

Figure 6. Electromagnetic torque at rotor asymmetry modes and torque dip compensating by developed device

The results of modeling the operation of an asymmetric motor with a forced setting of stator currents, implemented by means of the developed device, showed the effectiveness of solving the problem of compensating for the resulting dip in the torque of the induction motor [3].

4. Conclusion

Summing up, it is worth noting that despite the effective solution of the mechanical characteristic dip compensating problem using the developed device, one should take into account the decrease in the overall level of the motor electromagnetic torque at electrical asymmetry appears. If the engine torque level falls below the load torque level the electromechanical system will be unable to continue to perform its function. From the above it follows that measures must be taken to ensure the margin of the electromagnetic moment at the stage of motor design taking into account the maximum possible reduction in the electromagnetic torque at electrical asymmetry appears. The introduction of the surf factor by torque together with the use of the proposed device will solve the problem of eliminating the asymmetry effects to complete the production cycle without the need to use standby motors.

References

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