**The effect of voltage asymmetry on the operation of traction electrical equipment in transport**

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**Abstract.** The influence of asymmetric processes on the operation of traction electrical equipment in transport, in particular on electrified roads, is considered. To evaluate the asymmetry, you can use the rated voltage instead of the direct sequence voltage. It is shown that this asymmetry leads to the appearance of a reverse sequence voltage, as a result of which the maximum torque of the asynchronous traction motor decreases and its heating increases. The dependence of the effect of voltage asymmetry on the relative decrease in the service life of an asynchronous motor is obtained.

**INTRODUCTION**

With symmetrical three-phase consumers, all phases of the three-phase system are loaded evenly. If single-phase consumers also receive power from a three-phase system, then the load is unevenly distributed over the phases, which leads to a worse use of all elements of the three-phase circuit. An unbalanced load of power systems leads to unbalanced voltage losses in its elements, which ultimately leads to voltage asymmetry in three-phase consumers. The main non-traction consumers powered by the power supply system, electrified railways, are three-phase asynchronous motors and lighting devices. The unbalanced voltage at the terminals of three-phase motors leads to uneven loading of their phases and to high heating of the most loaded phases, and therefore it is necessary to reduce the load on the asynchronous motor. Single-phase electric locomotives in operation are high-power single-phase loads, and therefore great attention should be paid to the resulting asymmetry.

**EXPERIMENTAL RESEARCH**

In electrified railways, the power supply system is powered by overhead power lines from an infinitely high power supply with symmetrical voltage. In this regard, the voltage of the forward sequence is equal to the rated voltage, the voltage of the reverse sequence is zero. The voltage of the forward and reverse sequences for consumers will be equal to the voltage of the forward and reverse sequences on the buses of the supply center, minus the voltage drops, respectively, of the forward and reverse sequences in the transmission line [1-5].

In symmetrical circuits, a voltage drop in the forward sequence is caused only by the forward sequence current, and a voltage drop in the reverse sequence is caused by the reverse sequence current. The voltage drop is several percent of the rated voltage. To evaluate the asymmetry, instead of the direct sequence voltage, simply the nominal voltage is taken. The reverse voltage of an asynchronous motor is equal in absolute value to the reverse voltage drop in the transmission line and is opposite in sign. Studies show that the operation of asynchronous motors in non—symmetrical conditions leads to a decrease in the maximum torque of the asynchronous motor and, as a result, to an increase in its heating. During normal operation, a rotating circular electromagnetic field with a constant flow is created in the engine. In the unsymmetric mode, this field turns into an elliptical field, which can be decomposed into two circular fields rotating in different directions in accordance with the symmetrical voltage components of the forward and reverse sequences. All this is formed by torques acting in opposite directions. The maximum torque of an asynchronous motor is proportional to the square of the voltage at its terminals. In this regard, it is possible for engineering calculations to determine the total torque M as the difference between two moments [6-12].

M=M1-M2 where M1 is proportional to the square of the voltage of the forward sequence, and M2 the square of the voltage in the reverse sequence. In practice, the voltage of the direct sequence is approximately equal to the nominal one.

In this case M1=CU2nom, where C is the proportionality coefficient,

*M2=C(αu-Unom )2* (1)

At the same time α\_u - the coefficient of voltage asymmetry. Thus

*M=M1-M2 = CU2nom (1-αu2)* (2)

**RESEARCH RESULTS**

**If α\_u it reaches 0.1, then the moment change will be no more than 0.01.** In this case, the voltage asymmetry has no noticeable effect on the maximum torque of the asynchronous motor. The reverse sequence voltage has a much stronger effect on the heating of an asynchronous motor, because its reverse sequence resistance is much less than the resistance of the forward sequence, therefore, with a small reverse sequence voltage, the reverse sequence current is entirely inductive and is determined for a double frequency due to the rotation of the reverse sequence field in the direction opposite to the direction of rotation of the synchronous field with the same frequency. speed. Therefore, if the power factor of an asynchronous motor for the forward sequence is about 0.9, then for the reverse sequence, it is close to zero, and the active power, and in series, and the torque is small despite the high current. With the same voltage asymmetry coefficient, the angle between the symmetrical components of the forward and reverse sequences of the phases of the same name may be different. In the negative case, when there are forward and reverse phase currents in one of the phases of the stator winding, the total current should not exceed the nominal current [13-15].

*I1+I2=Inom* (3)

Here:

Reverse sequence resistance нmuch less short circuit resistance

Assuming that: and substituting this into formula (2), we get the permissible current of the direct sequence.:

(4)

Denoting the multiplicity of the short-circuit current in relation to the rated current of the motor through β, we have

(5)

It can be seen from Table 1 that with the multiplicity of the motor short-circuit current and % the available engine power, that is, the permissible load is zero

**Table 1.** The multiplicity of the motor short-circuit

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | Relationship I1/Inom when the value | | | |
| 0,05 | 0,10 | 0,15 | 0,2 |
| 3 | 0,85 | 0,70 | 0,55 | 0,40 |
| 4 | 0,20 | 0,60 | 0,40 | 0,20 |
| 5 | 0,75 | 0,50 | 0,25 | 0 |

The values in Table 1 give some reduced values of the permissible load due to the assumption that the angle between the currents of the forward and reverse sequences of one phase is zero, and the heat distribution between the windings of this heated phase and the windings of other phases was not taken into account. For a conditional traction load, the value and angle of the voltage asymmetry will change all the time and the different phases will alternately be loaded, then more, then less. Expression (3) gives the allowable load in the form:

(6)

Pnom – rated power of the engine.

When the values и you can get . В in other cases, the values .



**Fig. 1.**The dependence of the effect of voltage asymmetry on the service life of an asynchronous motor.

Dependence of the effect of non-voltage symmetry on the relative decrease in service life Т/ Тnom, T and Тnom the actual and nominal service life of the asynchronous motor.

**CONCLUSIONS**

The output power is obtained not much higher than according to formula (3). From formulas (3) and (4), it can be said that with a slight voltage asymmetry, it may be advantageous to turn off one phase of the stator and make the motor operate in single-phase mode, at which the torque can reach 70-80% of the nominal. From this we can conclude that a voltage asymmetry of more than 5% is unacceptable.

For traction load conditions, the value and angle of non-symmetry of the voltage will change all the time, and the various phases will be loaded more or less in turn. Figure 1 shows the dependence of the effect of voltage asymmetry on the service life of an asynchronous motor.

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