Research on thermal fault analysis of asynchronous motor based on simulation experiment

YanRong Li1*, FengKai Lin1 and Jie Zhu1
1 School of Electrical and Power Engineering, China University of Mining and Technology, Xuzhou, Jiangsu, 221116, China
*Corresponding author’s e-mail: 17185335@cumt.edu.cn

Abstract. With the continuous development of industrial society, electric energy has occupied almost all fields of life and production, which leads to the electric motor as its carrier playing an extremely important role in production life. Therefore, how to protect the motor and analyze its fault characteristics is of great practical significance. In this paper, by analyzing the structure and working principle of asynchronous motor, and combining the causes of thermal failure of asynchronous motor, the model of asynchronous motor under overload fault conditions is established, and MATLAB software is selected to further simulate and analyze the various states of the motor by changing its parameters. The final waveforms of the motor under different faults are obtained, aiming to promote the development of the field of thermal fault analysis and simulation of asynchronous motors in order to improve the stability of motor use.

1. Introduction
With the economic development and the construction of modern power grid, the production and living standard has been improved, and various kinds of electrical appliances have been popularized, electricity has a great influence on the development of the whole society, and is more and more widely used. Electricity is easy to control, easy to transmit, and has many sources, which makes it one of the most important energy sources in today's society. As the carrier of electric energy transmission, electric motor has an irreplaceable role in people's production and life, therefore, the research on electric motor has become a hot spot in the field of electric power.

According to incomplete statistics, there are nearly 20 million electric motors in China, of which about 3.2 million units are burned and damaged every year because they are not inspected and protected in time. And the damage of electric motor in production line and industrial accident will directly cause more losses [1]. Therefore, it is of key importance to protect the motor in the production process and people's life. In the field of simulation, MATLAB occupies a very important position, and it is the most commonly used among many computer simulation tools, which can be applied to various industries, such as the simulation of power grid equipment, the simulation of electric motors, signal and graphics processing, etc. In this paper, MATLAB is used to conduct simulation experiments with the aim of reflecting the research results in scientific waveform plots.

2. Theoretical analysis of three-phase asynchronous motor
2.1. Working principle of three-phase asynchronous motor
When a three-phase current flows in the stator winding, the rotating magnetic field rotates at a synchronous speed and is generated in the air gap [2]. The rotating magnetic field and the rotor
undergo relative cutting motion, generating an electric potential that can be determined by the right-hand rule. As the current flows through the rotor conductor, it interacts with the air gap magnetic field to generate an electromagnetic force. This electromagnetic force generates an electromagnetic torque in the same direction as the rotating magnetic field, causing the rotor to rotate [3]. The asynchronous motor has three operating states, motor, generator, and brake operation.

2.2. *Analysis of the heat generation process of electric motor*

The motor will generate losses in the process of various operations, and these losses will bring two consequences, one is to make the motor hot, and in serious cases, it will cause thermal failure due to overheating; secondly, it may affect the efficiency of the motor, and in serious cases, it will cause the efficiency of the motor to be greatly reduced or even damaged [4]. If the motor heats up too much in the process of operation, it is likely to cause the heat resistance of the insulation material to deteriorate and then reduce its insulation capacity, and the life of the motor and the safety and reliability of the operation process will be affected by it. Therefore, in order to compensate for the harm caused by this, we adopt two methods, one is to reduce the losses generated by the motor as much as possible, and the other is to optimize the thermal conditions of the motor as much as possible.

3. *Establishment and simulation of thermal fault model of asynchronous motor*

The use of sections to divide the text of the paper is optional and left as a decision for the author. Where the author wishes to divide the paper into sections the formatting shown in table 2 should be used.

3.1. *Asynchronous motor thermal failure principle*

Research shows that more than 90% of the damaged motors are caused by abnormal motor operation, among which overload, blocking, phase breakage, three-phase voltage unbalance, grounding and short circuit are the main causes [5]. In this chapter, the occurrence of thermal faults is verified for asynchronous motor overloads and power failures. First of all, the overload condition of asynchronous motor refers to the current flowing through the motor at a certain operating time that is greater than the rated current. The asynchronous motor overload capacity is the ratio of the maximum torque to the nominal rated torque, which is equivalent to the ratio of the maximum value of the asynchronous motor to the standard value of the actual load, the higher the ratio, the stronger the overload capacity of the asynchronous motor and the better the performance.

The following will summarize the three situations in which asynchronous motors produce overloads.

- When there is a fault in the machinery being dragged, and the running rotation is not flexible enough or stuck, the asynchronous motor will be overloaded, resulting in overheating of the motor winding.
- The mechanical load carried by the asynchronous motor does not work properly, and the mechanical load may be large or small during operation, resulting in overheating due to overloading of the asynchronous motor.
- The choice of mismatched equipment makes the load power of the asynchronous motor higher than the rated power, which causes the asynchronous motor to heat up in the case of long-term overload operation.

Asynchronous motors are subject to power supply failure as follows.

- Three-phase voltage is out of phase: the voltage is unbalanced, that is to say, the negative sequence component is too large, in general, 1% of the voltage unbalance will lead to 3% ~ 11% of the phase current unbalance, the negative sequence component is converted into heat because it can not do work, so it leads to the motor current increase overheating or even burned.
- Three-phase overvoltage and undervoltage: Generally speaking, three-phase motor has the highest efficiency under rated voltage. If the power supply voltage is too high, the no-load
excitation current will increase, which will lead to the decrease of motor efficiency and heat; if the power supply voltage is too low, the output power of the motor will decrease and lead to overload, which will cause the motor to block when running for a long time or in serious condition.

3.2. Establishment of asynchronous motor model and waveform analysis
In this section, using MATLAB software, the simulation sets the rated power of the motor to 2200 W and the rated speed to 1500 rad/min. Based on the rated parameters of the asynchronous motor, we calculate the rated load torque according to the formula: rated torque = rated power/rated speed. Note: The unit of power is watt (W) and the unit of speed is rad/s (rad/s). By the formula (1) gives \( T = \frac{9549 \times P}{n} \) (1)

When the model is built, the load torque is set to 10N/m. The waveform settings are set from top to bottom: rotor A-phase current, stator A-phase current, speed, and electromagnetic torque. The waveforms are set as follows: rotor A-phase current, stator A-phase current, speed, and electromagnetic torque.

From the analysis in Figure 1, it can be concluded that the rotor current and stator current both vary significantly during the initial trial start-up phase, and then start to vary smoothly with smaller periods during subsequent smooth operation, while the torque and electromagnetic torque are maintained at constant values. The electromagnetic torque is generated by the interaction of the active component of the rotor current and the stator rotating magnetic field, and its magnitude is proportional to the active component of the rotor current and the magnitude of the rotating magnetic field.

The concept of load torque refers to the torque required by the motor to drive the load. When the load torque exceeds the rated upper limit of the motor, overload operation of the motor will occur. Here we adjust the load torque of the asynchronous motor to 80 N/m and verify whether the asynchronous motor causes an increase in current under overload conditions, thus causing the asynchronous motor to overheat.
The simulation result of the overload operation state is shown in Figure 2. According to the graph, we can analyze and find that the overload state of the asynchronous motor produces and maintains a high periodic variation of the rotor current and stator current after the starting oscillation, and the amplitude of this variation is about 50 times of the normal condition. Meanwhile, due to the overload, the motor's turndown rate increases, causing the actual speed to start to drop and cannot reach the rated maximum value. The electromagnetic torque also increases due to the increase in rotor current and is maintained at a higher value.

The power supply overvoltage, power supply inverter, and power supply phase failure are all designed with a similar idea, using similar design thinking as the single-blade multi-set switch. The parameters of Breaker module are set as follows: the initial state of Breaker1 is set to normally off, the action starts at the 3rd second, and the action ends at the 4th second and returns to normal.
From the simulation effect of power supply overvoltage waveform (Figure 3), it is obvious that during the set fault time, due to the power supply overvoltage, i.e., the voltage increases from 220kV to 500kV, the rotor and stator current have a very obvious periodic increase, and the speed also exceeds the rated value, and the electromagnetic torque has a very violent periodic change. It means that the over-voltage of power supply will cause the motor current to increase, and the operation will cause the motor thermal failure to damage.

Figure 4. Power supply frequency conversion waveform diagram.

From the simulation effect shown in Figure 4, it is obvious that between the 3rd and 4th seconds of the fault time, the frequency of the power supply increases from 50Hz to 100Hz, and the rotor current and stator current both increase significantly, because this simulation is to do the power supply frequency conversion, so the current waveform is more chaotic due to the different frequency, and the speed also appears to decrease, and the electromagnetic torque also appears to oscillate and increase.

Figure 5. Power out-of-phase waveform diagram.
The effect of power shortage imitation is shown in the figure 5. From the figure, it can be seen that the state of phase shortage operation, that is, the initial phase angle of the current of phase A is changed from 120° to 0°, and the set fault makes the three-phase asynchronous motor only have 0° and 240° power input, the motor rotor and stator current changes are very obvious, both have a significant increase. At the same time, the speed of the asynchronous motor drops rapidly, and the electromagnetic torque takes a significant turn and then increases.

Figure 6. Load Sudden Change Waveform Diagram.

The simulation operation results of the sudden load change are shown in Figure 6, from which it can be seen that before the 3rd second time point, the motor is running under normal load, and the waveform effect of the first 3 seconds is the same as that of the normal condition. The first 3 seconds of the waveform effect is the same as the waveform under normal condition. After the 3rd second, the load suddenly increases and the asynchronous motor is in overload operation, at which time the rotor and stator currents both change significantly and increase to meet the torque output in the overload condition. At the same time, the motor speed decreases slightly, while the electromagnetic torque value increases.

4. Conclusion
In this paper, we mainly verify the occurrence of thermal faults in the asynchronous motor overload and power supply fault cases. In the simulation results of these five cases, we can clearly see the increase of current waveform, i.e., the fault characteristics of stator and rotor currents, and the occurrence of thermal fault of three-phase asynchronous motor is reflected by the increase of stator and rotor currents, and the change of amplitude of the current increase also reflects the degree of overheating of thermal fault. The magnitude of the current increase also reflects the degree of overheating of the thermal fault. The knowledge of these conditions also lays the foundation for the analysis and judgment of asynchronous motor thermal faults, and provides an important theoretical basis for the design of motor protectors based on the principle of current. It is hoped that more scholars will pay attention to this area in future research and provide new ideas for this field of study.

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