Research and improvement of leakage protection system in traction motor

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Abstract: Because the leakage protection circuit in traction motor of coal mining machine is impacted by frequency converter devices, malfunctions appear frequently. This paper makes an in-depth analysis, proposes a solution of using the subtraction circuit to offset interference signals and conducts a simulation analysis. The above scheme, which is simple and easily realized, can improve the reliability of leakage protection device in traction motor.

Key words: coal mining machine; traction motor; leakage protection; frequency converter

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Coal mine work in poor conditions, coal mining running in the mine must be subject to the working environment, in which leakage fault is one of the most common shearer failures. So, underground low voltage feeders must be fitted with leak protection devices or selective leakage protection device, to ensure that the feed line of leakage is cut off automatically. Our shearer grid uses the neutral point ungrounded system; for such a request, we mostly adopt the additional DC power supply protection in coal mining machine, which is to protect comprehensive, capacitive current compensation, the action value setting of simple features, but malfunction in actual production leakage protection device occurs, seriously affecting the normal production, so it is urgent to use both leakage fault detection and isolation of the coal mining machine to further solve the problem at the production site.

1 Basic principle of leakage protection system in traction motor of coal winning machine

Shearer traction motor generally adopts the additional DC power supply method for leakage protection. As shown in Fig. 1, the circuit is mainly composed of three-phase power reactors SK, zero-sequence reactance LK, capacitance C_O, DC power, the sample resistor R and insulation resistor R_0.

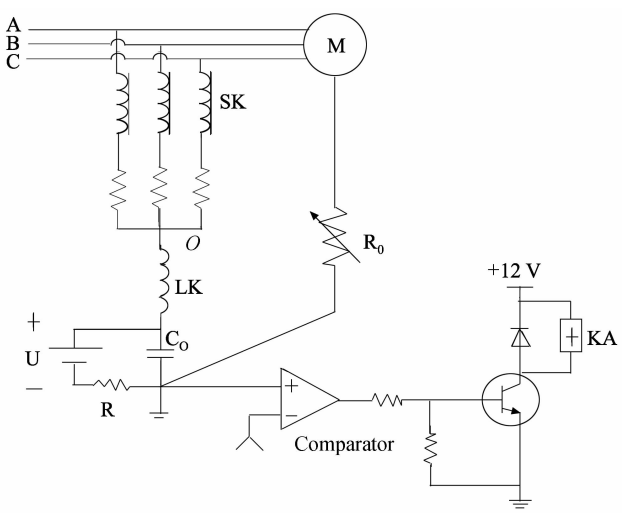

Fig. 1 Protection circuit with additional DC power

DC power passes through a three-phase reactor, comprises artificial neutral point, and is applied to the land between the three-phase grids. DC current flows out of the positive power supply, via LK and SK, into the three-phase grid, and then through the grid insulation resistor R_0 into the sample resistor R, finally back to the negative power. When the DC power supply achieves stability, the capacitor is open and no current flows. At this time the voltage on the sampling resistor R decreases with the increase of the grid insulation resistor; the voltage on the sample resistor R increases with the decrease of

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the grid insulation resistance. When the voltage on sample resistor R is less than the set value of the comparator, the motor does not leak, the comparator outputs at a low level, the transistor and the relay do not operate, so there is no need for protection; when the voltage signal on the R is greater than the predetermined value, motor does leak, the comparator outputs at a high level, and the transistor and the relay operate, so the protection sets off, enabling the power grid turn off and the motor can be protected.

Usually, before the shearer works, leakage detection should be conducted in order to reduce the accident and to protect the motor. Leakage locking, based on the principle of additional DC power supply method, can detect the failure and block the switch when the switch gate powers off and load-side network insulation resistance is lowered below the setting value, so that the switch does not switch on. When the rated voltage is 380 V, 660 V and 1 140 V, the corresponding action resistance value is 7 Ω, 22 Ω and 40 Ω respectively.

2 Current leakage protection circuit of traction motor of coal winning machine

In the actual production, after the coal mining machine is connected with the high voltage power supply, it adopts the same additional DC power leakage protection device to protect the traction motors, cutting motor and pump motor. However, the underground work is seriously affected because the malfunction phenomenon frequently appears in the traction motor protection device. Fig. 2 shows the traction motor leakage protection circuit.

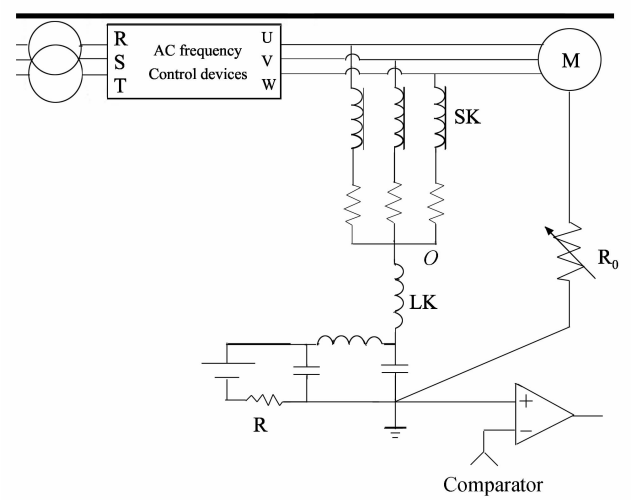

Fig. 2 Traction motor leakage protection circuit

Through measuring, it is found that the neutral point O of the circuit three-phase reactor point-to-ground potential is not zero, but the neutral point of the grid power O points on the ground potential is zero under normal circumstances of 50 Hz frequency. That is because the symmetrical three-phase sinusoidal AC power supply voltage or current vector is zero. However, the situation is different if the traction motor takes AC converter as a power source.

The waveform of AC inverter three-phase output voltage is similar to sine wave. As the AC frequency converter makes the output voltage waveform similar to the sine wave through the pulse width modulation (PWM), and the pulse width modulation (PWM) creates a desired waveform by pulse ranging from a series of rectangular pulses, the obtained output waveform are not perfect sine wave no matter what kind of PWM method is adopted. It has the dead zone and a series of high harmonics, so that the vector sum of the three-phase current or voltage is not equal to zero. Therefore, the original leakage protection circuit is still used, and its network neutral point to ground potential is no longer zero.

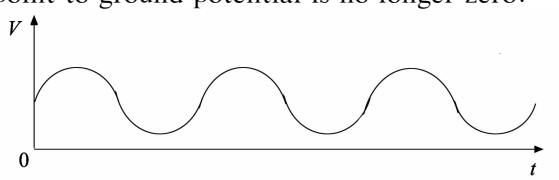

Fig. 3 Neutral point of the voltage waveform

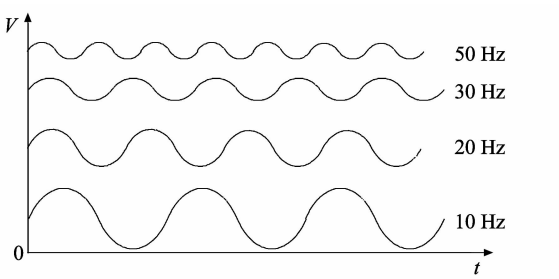

Fig. 4 Leakage signal waveforms with different inverter output frequencies

Fig. 3 shows the current leakage protection and detection circuit. When the motor leaks, the frequency of AC inverter output is 20 Hz. After the actual measurement of the network neutral point O, it is found that the voltage waveform to ground is an AC voltage which has the same frequency with the transducer. The same voltage signal can be got in the sample resistor R. The amplitude of the AC voltage increases as the frequency decreases. The period lengthens when the frequency decreases, and the neutral point O will have a voltage signal in a period. For example, if the period is 50 ms when the frequency is 20 Hz, then there exits AC voltage

signal at the neutral point O, and it has a greater amplitude. The leakage protection action is correspondingly soon enough to make sure that it has a leakage and thereby protects the circuit malfunction. Fig. 4 shows the actual leakage signal waveform when measuring various frequencies output of the inverter.

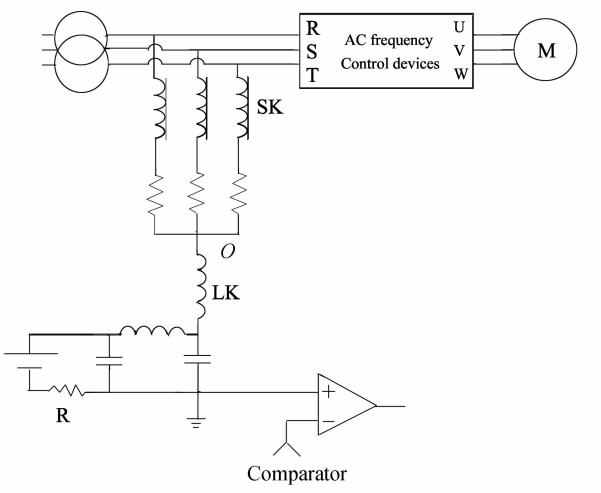

Fig. 5 Current Traction Motor leakage protection circuit

In order to avoid the interference of frequency control devices and overcome the impact of frequency control devices for traction motor leakage protection device, the coal mining in the actual production also takes a number of ways. By installing leakage protection device in front of the AC frequency converter, just as Fig. 5 shows, the leakage protection device is no longer subject to the impact of frequency control devices. The received voltage signal frequency is 50 Hz constantly which ensures the potential point-to-ground of the neutral point O is zero. It fully meets the requirements of leakage protection device to the neutral point of zero. However, we found that in the actual production, by changing the location of the leakage protection device, the inverter of the frequency converter will be affected due to the capacitor charging and discharging of the leakage protection circuit. The response time of signal transmission and implementation of the circuit should also be noted. General action response time of mining electrical leakage protection (including feed switch tripping time) should be less than 250 ms (660 V system) and 400 ms (380 V system) or 1 s (127 V system). If the motor has relative leakage somewhere and the protection action is not timely made, it may burn itself and even burn other power switching device. Therefore, under the premise of improving the detection and reliable action, it should first consider the fast response time of leakage protection circuit. The internal main circuit of the frequency control devices is made of the rectifier circuit, filter circuit and inverter circuit with longer cable and circuit complexity. The experiments show that after the change of the location of the leakage protection circuit, the leakage response time will be greater than the minimum response time. Then the timeliness of protection cannot be guaranteed, and it is not conducive to people and electrical equipment.

3 Improvement scheme of traction motor leakage protection circuit and simulation analysis

As shown in Fig. 6, the program uses the method of additional DC power supply, leading line 2 from the grid. The sampling resistor R signal is point P signal from line 1, which is produced by the DC signal and interference signal superposition. Because the voltage frequency of the neutral point equals to the output frequency of the inverter, the interference signal is the same with AC inverter output frequency and it is an AC voltage signal. In a period of time, when the amplitude is larger, the superimposed signal is strong enough for the judgment circuit to contend that the leakage has already occurred, thereby producing a disoperation; the point Q signal that line 2 gets contains no DC component, the AC voltage signal and AC inverter output frequency are completely the same. The two signals offset AC interference component produced by the frequency converter, retaining the DC component, and then reduce the malfunction rate of the motor achieved by a subtraction device.

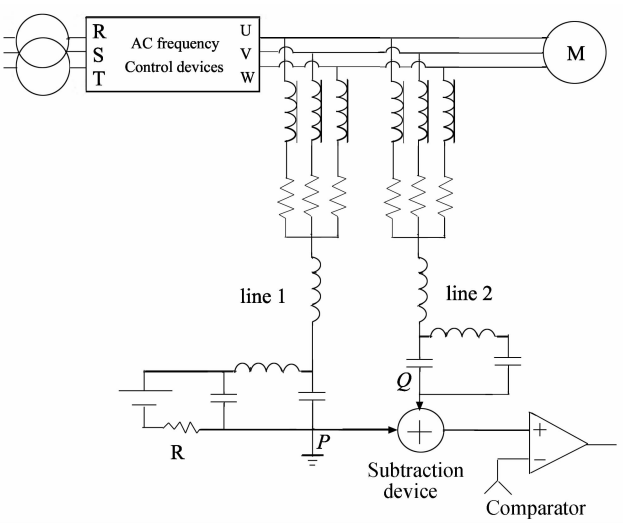

Fig. 6 Leakage protection circuit improved

When the motor works normally, there exits weak DC voltage signal in the sampling resistor R. Meanwhile the interference signals generated by the

inverter exist at the line 1 and line 2. After inputting the interfering signals in subtraction device, the interference signals are offset and the output remains to be weak DC voltage signal. After comparing the voltage signal and the predetermined voltage of comparator, the output is low level, and protection is not performed. When the motor leakage fault occurs, the DC component signal on the sampling resistor R increases, the subtraction filters AC interference signal of line1and line 2, getting the DC component of the signal. After comparison with set voltage value in the comparator, it can be judged as leakage after high level output, so the relay operates and the main loop disconnects.

In this scheme, when the inverter output frequency is 20 Hz, DC supply voltage is 36 V, the grid voltage is 380 V, the voltage waveforms of the sampling resistor during motor leakage are shown in Figs. 7 and Fig. 8 diagram below.

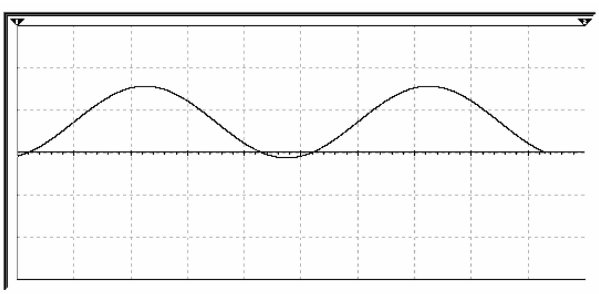

Fig. 7 Waveform at *P*-point

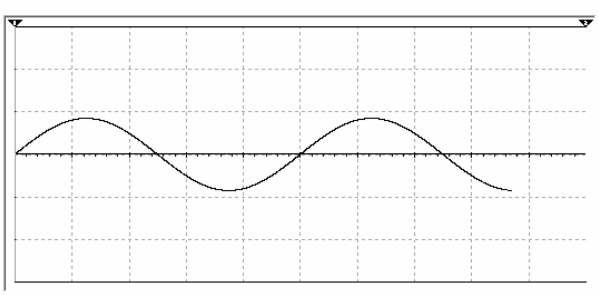

Fig. 8 Waveform at *Q*-point

In the simulation diagram the point *P* waveform is signal waveform of sampled resistor R, and it is the same as the actual measured voltage waveform of network neutral point (Fig. 4), which proves that the signal is superimposed by the alternating voltage signal and DC voltage signal. The signal on *Q* is consistent with the theoretical signal which does not contain the DC component. The AC voltage signal and the AC inverter output frequency are the same, the two input signals output DC voltage signal as shown in Fig. 9 through a subtraction device. The subtraction device offsets AC interference component to retain the DC component.

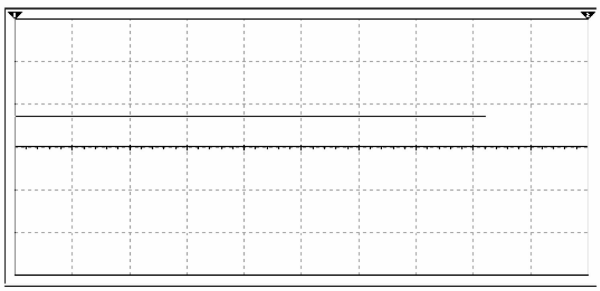

Fig. 9 Simulated signal waveform from subtraction device

Compared with the original leakage protection circuit, the interference signals generated by the AC frequency converter of the improved circuit are reduced. No matter how the AC frequency converter output frequency changes, a subtraction device can be used to offset the interference signal in real-time, retaining the DC component, so disoperation of traction motor caused by the frequency converter can be avoided. Therefore, the production can be improved and the protection circuit can protect the motor timely and reliably.

4 Conclusion

This paper analyzed the shortcomings of the current protection circuit by studying the shearer traction motor leakage protection circuit. The variable frequency speed control device for traction motor leakage protection circuit generates the interference problem. With the analysis of the interference signal, it is proposed to use a subtraction device to offset interference component, so that the motor is ensured to operate timely and reliably in the production process, avoiding unnecessary production halts and improving the production. Hence it is worth of widespread application.

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