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Research Article

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Based on the Research of Ball Mill Reactive Power Compensation Device and Harmonic Current

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ABSTRACT

In order to improve the power factor, mining enterprises used a large number of parallel capacitor, but its harmonic current is larger, aiming at this phenomenon, the paper used the method of parallel capacitor concatenated a certain size reactor, to improve the resonance point of parallel capacitor and system impedance, eliminated the system harmonic. There designed the simulation model of ball mill asynchronous motor reactive power compensation device, from the results, the reactive power compensation and harmonic governance had better results for the device.

Keywords: power factor, reactive power, harmonic component, electric reactor, compensation circuit

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INTRODUCTION

In the mining enterprises, the load can consume large amounts of reactive power, these reactive power not only cause the consumption of grid electricity, but also the power factor had reduced, the usual way is to increase reactive compensation device. According to the relevant statistics, in the all consumed reactive power in industrial and mining enterprises, reactive power consumption of asynchronous motors accounted for 60%-70%. As the important equipment of ore dressing, ball mill can been widely used in gold ore, iron ore, copper ore and other mining enterprises, but a lot of ball mill rely on asynchronous motor drive to work, as a large dressing equipment, it had considerable electricity consumption. The paper introduced a kind of reactive power compensation circuit, the circuit consisted of reactor, capacitor, resistance, It not only can improve the power factor, prevent the harmonic current injected into the power grid, but also can inhibit the resonance between the reactive power compensator and electric network.

2. The reactive power and power factor of non-sinusoidal circuit

In the industrial power grid, these parameters have the same physical significance, such as active power P, apparent output S and power factor $\cos\varphi$, whether in the non-sinusoidal circuit containing harmonic or in the sinusoidal circuit. But in the usual industrial power grid, the voltage waveform distortion is generally relatively small when the circuit contain harmonics, but the current have a relatively large waveform distortion. So under normal circumstances, the voltage waveform distortion can not be considered, it can been seen a sine wave, the current waveform is considered as a non-sinusoidal wave, if U is the effective value of sine voltage, I is the effective value of the distortion current, φ_1 is the Phase-angle difference between the fundamental current and voltage, I_n is the effective value of the N harmonic, Q_f is the power generated by the fundamental current, D is the reactive power by harmonic current generating. Considering the active power is not generated between the voltage and current with different frequencies, so it can obtain:[1]

$$P = UI_1 \cos\varphi_1$$
$$Q_f = UI_1 \sin\varphi_1$$
$$P_2 + Q_f^2 = U^2 I_1^2$$
$$S^2 = U^2 I^2 = U^2 I_1^2 + U^2 \sum_{n=2}^{\infty} I_n^2$$
$$D^2 = S^2 - P^2 - Q_f^2 = U^2 \sum_{n=2}^{\infty} I_n^2$$

At this time, the power factor is:

$$\lambda = \frac{P}{S} = \frac{UI_1 \cos\varphi_1}{UI} = \frac{I_1}{I}\cos\varphi_1$$

From the foregoing, the power factor is determined by two factors with fundamental current phase shift and current distortion.

3. The reactive compensation of low voltage parallel capacitor

Extensive use of inductive loads will cause the loss of the grid power factor in the mining enterprises. For the economic operation of the power grid, it usually had parallel capacitor, and had reactive power compensation. For example in a ball mill, it usually uses asynchronous motor when $P_E < 2000kW$ (P_E is rated power), it usually uses synchronous motor when $P_E > 2000kW$. The paper used the $P_E < 2000kW$ of the ball mill, the power loading used asynchronous motor, so it is necessary for effective reactive power compensation.[2]

3.1 The design of the reactive power compensation circuit

Due to the starter is connected with $Y-\Delta$, the motor has reactive power compensation as shown in Fig1

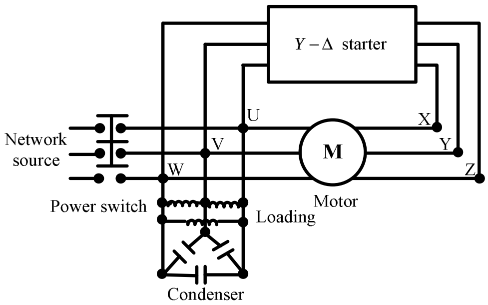

Fig.1. the reactive power compensation circuit of no series reactor

3.2 The selecting of parallel capacitor

Reactive compensation to on asynchronous motor not only can improve the power factor of power grid, and can improve the voltage quality. In the harmonic current damping circuit, the method is commonly used in situ reactive power compensation: Direct parallel capacitor on both ends of the equipment. Because of the parallel capacitor in the circuit, the total impedance of capacitor circuit decreases, current increase, according to the different series reactance ratio, capacitor voltage between terminals produce different levels voltage rise, so the selected capacitor must be able to withstand the voltage rise and not overload use. Due to the particularity of the ball mill load, it often appears three-phase unbalanced.

According to the principle of split-phase inequality based on local compensation, the estimation formula of compensation capacity：

$$Q_c = P\times(\tan\theta_1 - \tan\theta_2) = P\times\left(\sqrt{\frac{1}{\cos^2\theta_1}-1} - \sqrt{\frac{1}{\cos^2\theta_2}-1}\right)$$

Where: P is active power； $\cos\theta_1$ is power factor before improvement； $\cos\theta_2$ is power factor after improvement.

Take the medium high voltage asynchronous motor of YKK5001-4P-900KW-10KV mine ball mill for example, its power factor is $\cos\theta_1 = 0.84$ before compensation, power factor is $\cos\theta_2 \geq 0.93$ (average 0.94) after compensation, power consumption reduce 5%, production increase ＞6%. If the parameters achieve these targets, the compensating parameters of the system is $Q_c = 225.63\text{KVAR}$, due to compensation capacity Q_c not only is influenced by the voltage change of short_net access point, but also make the whole grid voltage is increased, compensation capacity Q_c can be made appropriate amplifier, the compensation capacity is determined to be $Q_c = 230\text{KVAR}$. The reactive power compensation model used the high voltage parallel capacitor model was BAM1.05-30 to 1 w. Its rated voltage is $V_{rate} = 1.05K\text{V}$, its rated compensation capacity is 30KVAR, its rated capacity is $86.6\mu F$, the number of capacitor will be altogether eight.[3]

From the foregoing，the reactive power after parallel capacitor significantly reduced, the transformer capacity has also been effectively used. Due to the reactive compensation capacity is proportional to the square of the supply voltage, and more serious is that it can influence each other between it and the harmonic. The fundamental current of capacitor is superimposed on the harmonic currents, so the compensation circuit will show three results: (1) Compensation circuit can normally work in the case of without Often operation and circuit harmonic has no effect on capacitor overload running; (2) In most cases, superposition of harmonic current increase the effective value of the capacitor current and the temperature rise of condenser, it can give rise to condenser temperature too high, and reduce its service life, there may even make the capacitor burned; (3) Capacitors amplified harmonic currents, it has great harm to the capacitor itself and the electrical equipment, even it can destroy the normal operation of electric network. So at the same time of reactive power compensation, the harmonic of power grid is suppressed as far as possible, So that the grid power get the best power factor.

4 The processing of reactive power compensation harmonic

At the same time of compensating reactive power, in order to suppress the harmonic of power grid, the paper used the method of series a certain size reactor for parallel capacitor, the purpose is chang the resonance point of parallel capacitor and the system impedance, so it avoid resonance.

4.1 The design of harmonic elimination circuit

The circuit harmonic problem is increasingly serious, it is necessary to establish harmonic damping circuit. It can effectively reduce the circuit harmonic and suppress the surge current when the capacitor input. Due to the N harmonic impedance of the system is much smaller than the N harmonic reactance, the N harmonic reactance of the system can be ignored. Such the harmonic damping circuit consisted of capacitors and reactors. As shown in Fig.2.

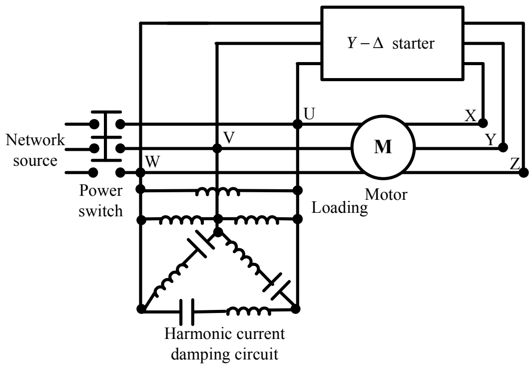

Fig.2. the reactive power compensation circuit of the series reactor

4.2 The processing of harmonic elimination circuit

If : I_{sn} is harmonic current into the grid; I_{Cn} is harmonic current into the capacitors ; I_n is the N harmonic current of the harmonic source; X_L is the fundamental reactance of series reactor; X_C is the fundamental reactance of paralleling reactor; X_s is the short-circuit reactance of power frequency. So, after the series reactor:[4]

$$I_{sn} = \frac{nX_L - X_C/n}{nX_s + \left(nX_L - X_C/n\right)} I_n$$

$$\Rightarrow \frac{I_{sn}}{I_n} = \frac{\left(nX_L - X_C/n\right)/nX_s}{1 + \left(nX_L - X_C/n\right)/nX_s}$$

$$I_{Cn} = \frac{nX_s}{nX_s + \left(nX_L - X_C/n\right)} I_n \Rightarrow \frac{I_{Cn}}{I_n} = \frac{1}{1 + \left(nX_L - X_C/n\right)/nX_s}$$

The parallel resonance of the capacitor and the system occurs in $1 + \left(nX_L - X_C/n\right)/nX_s = 0$, the harmonic order of resonance point is $n_0 = \sqrt{X_C/(X_L + X_s)}$. The harmonic order of resonance point is lower than the harmonic order without series reactor, the greater the series reactor inductance, the lower the harmonic order n_0. Therefore, by adjusting the series reactor inductance to control the position of the parallel resonant point, it can avoid each harmonic of harmonic source. In discussing how to switch capacitors, it focused on how to set up the corresponding inductance of compensation reactor after switching parallel capacitors. In order to realize the effect of reactive power compensation, the purpose is to minimize the negative effect of harmonics produced by parallel capacitor.

4.3 The selected of series reactor

When the capacitor installed in the circuit with harmonic, it usually add 6% series reactor, the bigger place of the 3 harmonic, such as arc furnace etc. usually add 13% series reactor, if the harmonic content is quite large, it can use 15% series reactor, if the loop has the higher 5 harmonic, it usually should add 6% series reactor, but 4 harmonic can't exist, and the 3 harmonic current may be amplified, it can also add 8% series reactor, in this way, it can help the harmonic current reduce to 1/2 times when adding 6% series reactor, and it makes possibly the3 harmonic current amplification; it usually uses 6% series reactor after the7 harmonic. [5]

Harmonic current damping circuit and reactive power compensator are connected in series, they are connected in the power supply circuit with the load. Compared with the existing technology, the reactive power compensation circuit has the following advantages: Firstly, the harmonic between the grid or load and reactive power compensator can be effectively suppressed; Secondly, it can prevent the reactive power compensation device may produce harmonic current into the grid.

When the compensation capacity of ball mill asynchronous motor is about 225.63KVAR, in order to prevent the influence of the system harmonic effects on capacitor after the high-voltage compensation device put into operation, and in order to prevent the harmonic amplification, the design should consider some or all of harmonic is absorbed. For this purpose, the 6% inductive reactance of the capacitance be added in each capacitor branch, the purpose is to prevent the surge current and adsorb the 5、7、9 harmonic current, and the same time, it need reserve the position of the adding reactor, on the basis of the 3 harmonic overweight, it is then governed after the system stable operation.[6]

5. The analysis and research of ball mill reactive power compensation circuit on harmonic current treatment

5.1 The simulation model of ball mill reactive power compensation circuit on harmonic current treatment

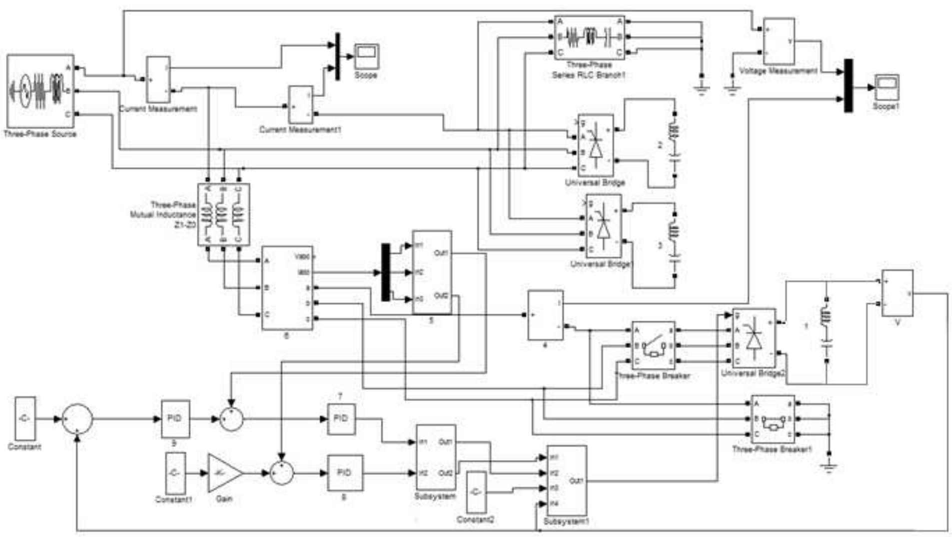

Fig.3. The simulation model of ball mill reactive power compensation circuit

5.2 The simulated analysis of ball mill reactive power compensation circuit on harmonic current treatment

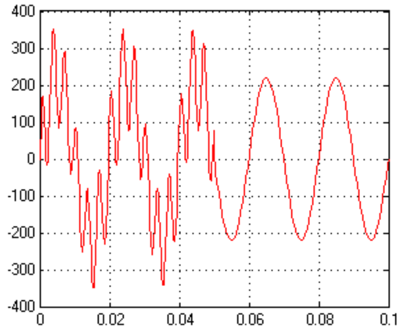

Fig.4. The current waveform before and after the harmonic filtering

Fig.4 is the voltage and current waveforms before and after the harmonic filtering, from the simulation result, the harmonic suppression power can't work before $t = 0.05s$, the harmonic suppression power can work when $t = 0.05s$, so the total current in the grid don't basically contain harmonic components. If the harmonic suppression function begin to work when $t = 0$, the results shown in Fig5,6,7,8, where a is the total current of power output, b is network voltage.

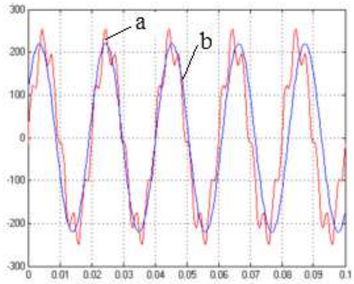

Fig.5. The network voltage and the total output current after filtering the 9 harmonic

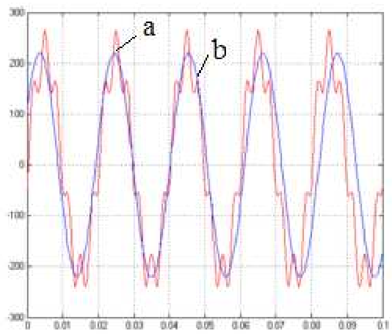

Fig.6. The network voltage and the total output current after filtering the 7 harmonic

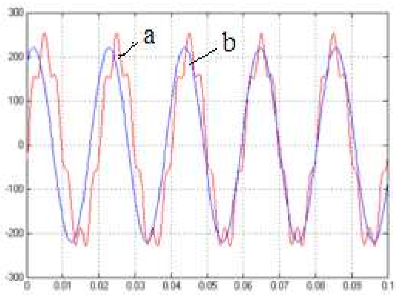

Fig.7. The network voltage and the total output current after filtering the 5 harmonic

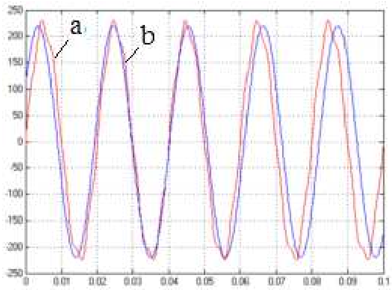

Fig.8. The network voltage and the total output current after filtering the 3 harmonic

From Fig5, 6, 7, 8, after increasing reactive power compensation circuit and harmonic processing, the quadergy exchange between the output capacitor and the grid increases, the distortion of voltage fluctuation is very small, so it is generally not considered. After the reactive compensation devices put into work, it not only absorbs active power, but also absorbs the reactive current and harmonic component of the load current. But it can only compensate and offset part of reactive power and harmonic in the load when the current capacity is limited. From Fig8, the total current flowing from the power grid almost no longer contain reactive power and harmonic components, from the point of view of the power grid, after the reactive compensation devices put into work, the current is sine wave and it is almost as voltage in phase, the power factor is almost close 1.

CONCLUSION

Through the above analysis, according to the overflow ball mill, to establish a high-performance reactive power compensation circuit is very necessary, the device increased the shunt capacitance compensation and series inductance, improved the power factor and reduced the harmonic of the circuit, these can save electrical energy, reduce the loss, improve the quality of power supply, it has good economic and social benefits for mining enterprise.

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