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Residual current compensation for single-phase grounding fault in coal mine power network

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ABSTRACT

The way of neutral point to earth via full compensation arc suppression coil can solve the problem of residual current compensation in coal mine power network effectively. Based on the analysis on the grounding current detection results of Xieqiao coal mine, the conclusion that harmonic component of grounding current is dominated by higher harmonics with complex harmonic sources in coal mine power network system was obtained. The influences of harmonic source type and fault point position on harmonic voltage and harmonic current were analyzed theoretically. The influences of earthed fault feeder detection result and the estimation errors of parameters to earth on residual current compensation were analyzed. A new thought of residual current prediction and the selections of model method and control method were proposed on this basis. The simulation results prove that harmonic amplitudes of zero sequence voltage and zero sequence current are determined by harmonic source type as well as fault point position in coal mine power network, and also prove that zero sequence voltage detection can avoid the unstable problem of coal mine power network system caused by undercompensation of capacitive current. Finally, the experimental device of full compensation arc suppression coil is introduced.

1. Introduction

Electric power of the mining power network is supplied by power cable in china mostly and the mine underground environment is bad, so there is high probability of single phase current leakage fault or single-phase grounding fault .The residual component of grounding fault current becomes higher and higher and the accident such as exploding or breakdown of power cable may happen frequently with the widely use of non-linear load and cable, it affects normal production and also threatens the safe operations of electrical equipments and the personal security of operating personnel. So the correct detection and investigation on grounding fault current in power network and the solution of the problem of residual current compensation are important for ensuring coal mine safety [1].

Full compensation arc suppression coil which can be installed in coal mine power network for solving the problem of residual current compensation is superior to the traditional type. The problem of residual current compensation has already been studied by domestic and foreign scholars in recent years. Three kinds of compensation modes are given in the reference, but the harmonic component of grounding current is neglected; a master–slave full compensation arc suppression coil which can change the inductance on second side of it is introduced in the reference, unfortunately, its operation must depend on earthed fault feeder detection result; a kind of zero residual current arc suppression coil which have three-phase five-limb structure and two secondary windings is proposed in the reference, but the method of residual current detection is emphasized on the using of mathematical tools, the algorithm is complex and requires more computational time [2–4]. A system model can be built when single-phase grounding fault system is analyzed. In the above references, the result of residual current prediction induced by the inaccuracy of the system model is incorrect usually.

The grounding current detection data of Xieqiao coal mine were researched in this paper, the conclusion that the harmonic component of grounding current is dominated by higher harmonics with complex harmonic sources was obtained. Then the influences of harmonic source type and fault point position on harmonic voltage and harmonic current were analyzed. The influences of earthed fault feeder detection result and the estimation errors of parameters to earth on residual current compensation were analyzed subsequently. In order to accomplish zero sequence voltage detection and specific harmonic suppression, a new thought of residual current prediction and the selections of model method and control method were proposed.

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The simulation results prove that harmonic amplitudes of zero sequence voltage and zero sequence current are determined by harmonic source type as well as fault point position, zero sequence voltage detection can avoid the unstable problem of coal mine power network system caused by under compensation of capacitive current, and full compensation arc suppression coil which uses the new methods has perfect effect for compensating residual current.

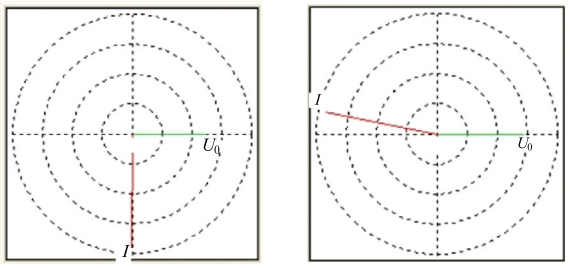
2. Grounding current detection results and analysis

For getting the data of harmonic component of grounding residual current, the experiments of high resistance grounding and bolted grounding fault were conducted on 6 kV I bus and III bus of Xieqiao coal mine respectively, the line test results were obtained by power line harmonic analyzer.

2.1. High resistance grounding fault occurring

Grounding current contained almost no active component (contained harmonic component) when arc suppression coil was not running. The harmonic component of 6 kV I bus was composed mainly of 11th, 19th, 23rd, 29th and 31st harmonic, and the harmonic component of 6 kV III bus was composed mainly of 5th, 13th, 19th, 23rd, 25th, 29th and 31st harmonic, the proportions of each harmonic were all low. When arc suppression coil was working, grounding current contained active component. The harmonic component of 6 kV I bus was composed mainly of 11th, 19th, 25th , 29th and 31st harmonic, the harmonic component of 6 kV III bus was composed mainly of 5th, 11th, 17th, 19th and 29th harmonic, and the proportions of each harmonic were also low.

High resistance grounding fault has little influence on power system, and the voltage amplitude of ground phase does not decrease significantly. When arc suppression coil is not working, the damping resistances of it are not cut off and do result in the existing of active component. These conclusions are verified by Fig. 1.



(a) Angle between U_0 and I was -90.94° (b) Angle between U_0 and I was 168.26°

Fig. 1. Relation graphs of the fundamental phases of grounding current I and zero sequence voltage U_0 with arc suppression coil or without it.

2.2. Bolted grounding fault occurring

When arc suppression coil was not working, grounding current contained almost reactive component and was rich in each harmonic. As shown in Fig. 2, active component of grounding current of 6 kV I bus increased when arc suppression coil was running, harmonic current was composed primarily of higher harmonics, and the 13th and 23rd harmonic current were particularly acute. Relatively, grounding current of 6 kV III bus contained more active component with high content of the 3rd, 13th and 23rd harmonic current. Take the analysis of the grounding current of 6 kV I bus as an illustration, active component of grounding current was small when arc suppression coil was not working, on the contrary, there was a sensible increase in active component visibly.

The harmonic component of grounding current is the result of the voltage distortion caused by harmonic sources of power side and load side, and it has a high content of 23rd harmonic current. This because the capacitance to ground has amplifying action to harmonic, and the harmonic current at the grounding point which is induced by harmonic voltage becomes n times of itself. This implies that the harmonic current at the grounding point caused by the harmonic voltage which the frequency of it is higher is bigger.

Because the harmonic component of grounding current is based mainly on higher harmonics in coal mine power network, specific harmonic suppression is more appropriate for the system of neutral point to earth via full compensation arc suppression coil for ensuring the compensation effect of residual current compensation.

3. Analysis on the system of neutral point to earth via full compensation arc suppression coil

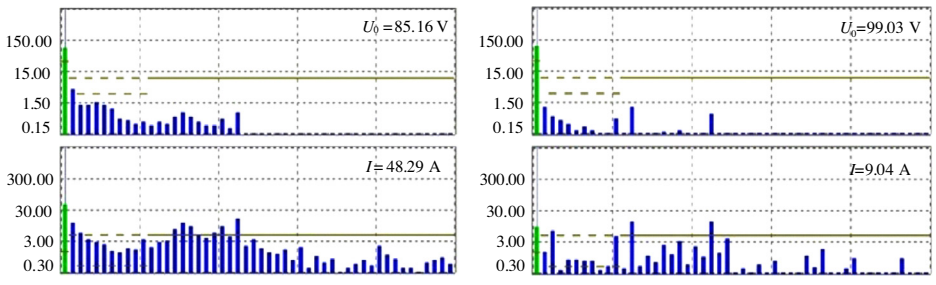
3.1. Analysis on the single-phase grounding fault system

The transient components of zero sequence current at fault point can be neglected when grounding fault is in a stable condition. The first section shows that the harmonic amplitude of grounding current in coal mine power network is resulted from the effects of power side harmonic source and load side harmonic source, so we can use superposition theorem analysis method [5]. The system model of the grounding fault feeder line can be equivalent to the circuit shown in Fig. 3. The equivalent power harmonic voltage source u_S, the internal resistance of it Z_S and the equivalent load harmonic current source i_{lh} are shown in the Fig. 3. The fault point is marked by X, and xZ_l is the line impedance between bus and fault point.

Before a fault occurs, the voltage at fault point can be derived from Fig. 3.

$$u_X = u_S \cdot \frac{(l-x)Z_l}{Z_S + lZ_l} + i_{lh} \cdot (xZ_l + Z_S) \tag{1}$$

The following conclusions are educed by Eq. (1). If the phases of the two harmonic sources are synchronous, the amplitude of the



(a) Arc suppression coil was not running (b) Arc suppression coil was running

Fig. 2. Harmonic histogram of zero sequence voltage U_0 and grounding current I.