THE GROUNDING PROTECTION BASED ON THE 5TH HARMONICS' COMPONENT FACING A SEVERE CHALLENGE

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INTRODUCTION

"The distribution of 5th harmonics in compensating network is the same as the fundamental wave in the neutral isolated networks", it means the 5th harmonics exist naturally in the network cannot compensate by the arc-compensating coil. .Under such theory, which firmly believed in the world [1] [2], the grounding fault protection relay was designed and put into operation. There are more than ten thousand of such relay protection installations put into operation in the past 20 years since mid of 80 of 19 century to the beginning of 20 century in China. But it is sorry to say that the operation effects are not ideally in common. Some people complained that the main causes are the contents of 5th harmonics are too weak. But there are other conclusions after we carried out more than thousand dynamic analogue tests in the laboratory. We found that the 5th harmonics inject into the network from the feeder which supplies the non-linear loads are the main reason to cause the failure of the grounding fault protection. For to check the objectivity of the test results in dynamic analogue tests and the reliability of our inference, the artificial grounding tests had carried out in two networks. They are one in a compensating network and another one in an neutral isolated network. In this paper we analysis the waveform we collected from the tests (under low resistance grounding, high resistance grounding, grounding phenomenon at the transient state and in the steady state etc.) in different condit6ions. We take care comparison to the 5th harmonics exist in the grounding fault of the two networks and compare with the waveform from the dynamic analogue tests. The objectivity of the conclusion from the dynamic analogue tests is proven.

The harmonics injected to the network from the non-linear loads throw down the gauntlet to the grounding fault protection scheme based on the theory that the 5th harmonics exist naturally in the network... How to precisely evaluate and application of the theory that the 5th harmonics exist naturally in the network is so important and have a lot of works to do ahead, especially under the state that now the grounding fault relay protection based on the transient components of the grounding fault had successfully used.

1. Dynamic analogue test in the laboratory

During year 2004, we found in the dynamic analogue tests unforeseen that the phase between the 5th harmonics component of the zero sequence current of the faulted feeder and the healthy feeder are sliding always and its amplitude are fluctuate respectively. It can shown in the figure of the waveform of a analogy neutral isolated network under thoroughly grounding condition (Fig.1) and neutral grounding through a transition resistance (Fig.2).

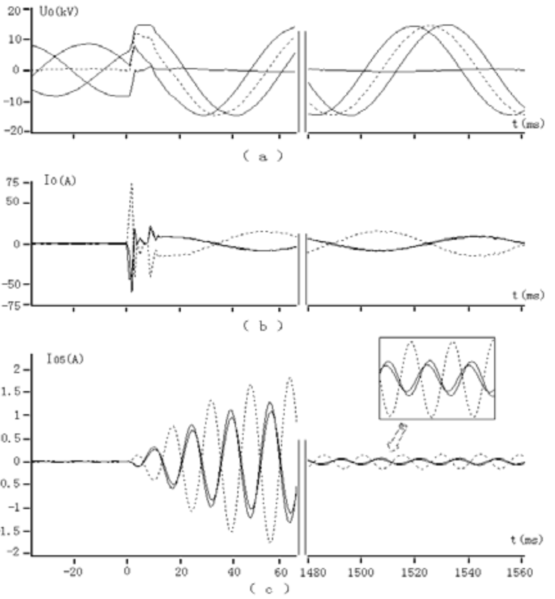

Fig.1 Waveform of neutral thoroughly grounding of a analogy neutral isolated network

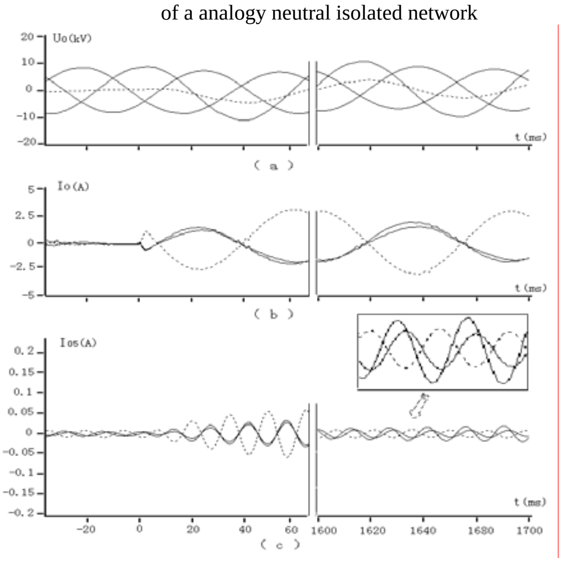

Fig. 2 Waveform of neutral grounding through a transition resistance of an analogy neutral isolated network

In the upper figures each of them contains three parts. (a) the dotted line is the zero sequence voltage Uo and the another three real lines are the voltage of the three phases respectively; (b) the dotted line is the zero sequence current of the fault feeder Io, and the other two real lines are the zero sequence current of the healthy feeders; (c) represents the respective 5th harmonics component $I_{0\,5}$ *of the current in (b).*

It is the same expression for Fig.3 to Fig.6.

To comparison the Fig. 1&2, we can find:

1. The I_{05} have the following characteristics during thoroughly grounding fault happened: the amplitude of the transient is relative large and the phase relation between faulty feeder and the healthy feeders are reversed, see in Fig.1©. The amplitude of the steady state is only one tenth of the transient or even more smaller, and there happened a small fluctuation on the amplitude and phase angle in all the feeders, see in Fig.1©.
2. During the grounding fault through resistance, the I_{05} have the following characteristics: to compare with the thoroughly grounding, the amplitude of the transient reduces sharply and the phase relation between faulty feeder and the healthy feeder are basically reversed.

   The amplitude and the phase relation of the feeder under steady state have a violently upheaval without order. The amplitude of the faulted feeder dropped from the first order in the transient state to second or third or even more low as seen in Fig.2©.

2. Result checking by the grounding test on existing networks

For to checking the results gained from the dynamic analogue test, we select two existing networks to test. The capacitive current to ground of the neutral isolated network is about 3.4A and the capacitive current to ground for the compensating network is about 41A.

2.1 Data gained from the test on a neutral isolated network

The waveform gained from the test of a neutral isolated network during thoroughly grounding is shown in Fig.3.

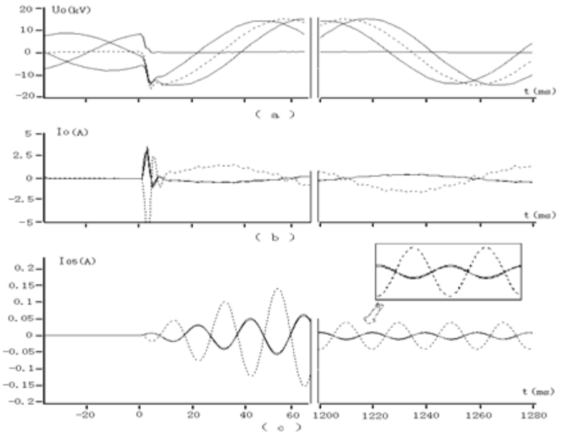

Fig.3 Test on a neutral isolated network during thoroughly grounding

The waveform gained from the test of a neutral grounding through resistance is shown in Fig. 4.

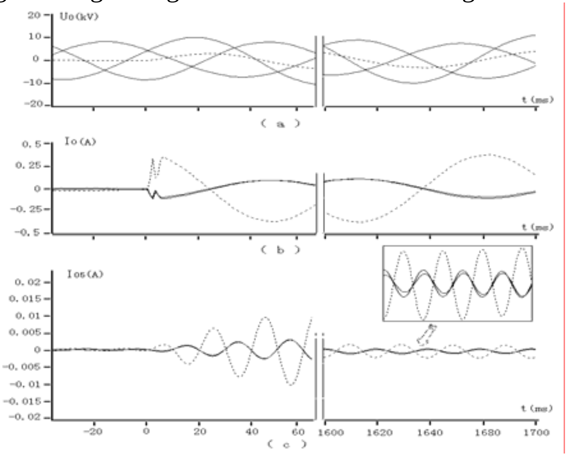

Fig.4 Test on a neutral isolated network grounding through transition resistance

2.2 Data gained from the test on a neutral compensating network

The waveform gained from the test of a neutral compensating network during thoroughly grounding is shown in Fig.5.

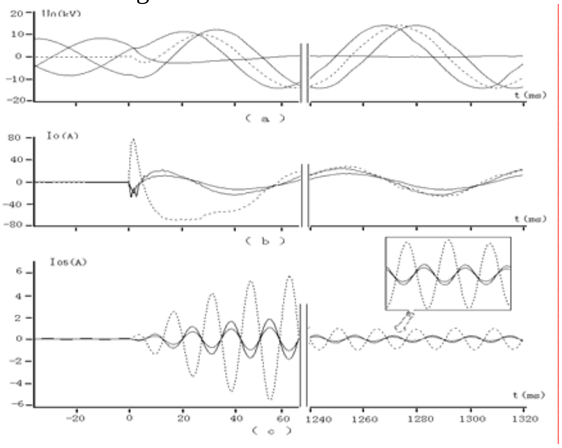

Fig5 Test on a neutral compensating network during thoroughly grounding

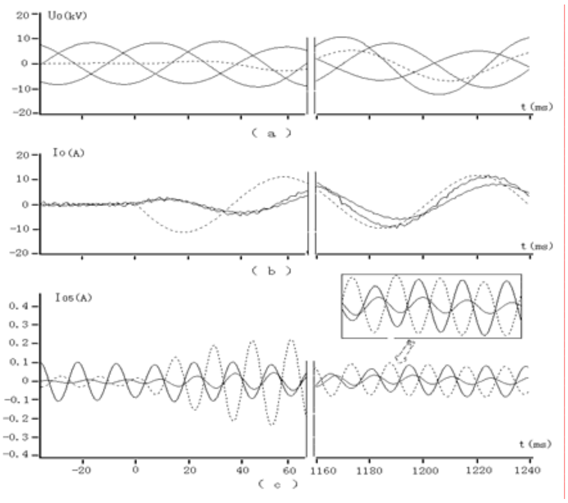

Fig.6 Test on a neutral compensating network during grounding through a transition resistance

The waveform gained from the test of neutral compensating network grounding through a transition resistance is shown in Fig. 6.

It can seen from the above waveform gained that the result is mostly similar as the result in dynamic analogue test, the only difference is during the steady state of a high resistance grounding the phase angle and the amplitude change of the 5th harmonics of the faulty feeder and the healthy feeder are more great.

The phenomena and the regularity are much similarly between Fig. 3&4, Fig. 5&6 and Fig. 1&2. They are:

1) The influence of grounding fault resistance to I_{05}. The I_{05} reached maximum during thoroughly grounding; and it drop down obviously during grounding through resistance. So it can be deduced that I_{05} will come to zero when the grounding resistance increased continuously.

2) The difference of I_{05} between transient state and steady state To compare with the transient state and steady state, not only the amplitude have few times to more than tenth difference but also the stability of the phase angle is not the same. In the transient state the phase angle keep steady and basically in reverse phase relationship; and in the steady state the amplitude and phase relation are uncertainty.

According to the peculiarity shown in the waveform, we can conceived easily that during the single phase grounding fault the I_{05} of the zero sequence current is not singly supplied by the system, it contains the part inject from the non-linear load. Their changes are without any order and its effects are no ordered too.

3. Waveform analysis

For to steady easily, in the analysis of the waveform in Fig. 5&6 we had first to established an equivalent circuit to reflect the changing rules of the 5th harmonics in Fig,5©&6©. The equivalent circuit diagram is shown in Fig.7.

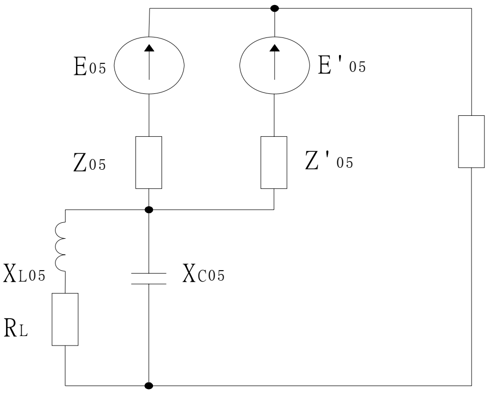

Fig. 7 Equivalent circuit diagram for 5th harmonics signal

In the figure, E_{05}, E'_{05} represents the equivalent potential of the 5th harmonics in system sources and from the nonlinear loads; $Z05$, Z'_{05} are their equivalent inner impedance, $Z_{05}<<Z'_{05}$ and assumed $E_{05} \approx E'_{05}$; R_F is the grounding fault resistance; X_{C05} and X_{L05} represents 5th harmonics capacitance and arc suppression coil inductance of the network to ground respectively; R_L is the equivalent resistance of the arc suppression coil

Then it is easily to explain the phenomena in Fig. 5&6:

1) When R_F——>0

During transient state, E_{05}, E'_{05} directly charge the capacitance to ground, due to the inner resistance of E_{05} is relative small, its charging current is so large and play a leading effect; and E'_{05} have a relative large inner resistance so that the charging current is small, it didn't destroyed the original reverse phase relationship, as shown in Fig.5©.

As it enter the steady state, the effect of the E_{05} reduced suddenly and the effect of the E'_{05} cannot be neglected, the reverse relationship of the faulty feeder and healthy feeders are not exist then and the change are without any rules.

2) When $R_F \neq 0$

During transient state, the effect of E_{05} relative reduced and the effect of E'_{05} enforced, influence the disturbance of amplitude and phase angle of I_{05}.

As it enter the steady state, the effect of E_{05} reduced and the effect of E'_{05} increased relatively, the disturbance to the I_{05} become more serious, so the relationship of phase angle and amplitude cannot take as a reference to decide the fault feeder.

4. Conclusion

1) The results gained from the dynamic analogue test and the test in the exist network are mostly similar. It indicates their physical characters are same. Their mutual corroboration is fully effective.

2) It can seen from the dynamic analogue test and the test in the exist network, the relay protection based on the 5th harmonics can only got the satisfied criterion during the fully grounding fault (or low resistance grounding fault). But such grounding fault condition is only a special case in the common grounding faults. So, if we discuss it in essence, such grounding fault protection scheme is un-valuable in practice.

3) Grounding test in the real networks is an important and effective way to examine the grounding fault protection scheme. But if the test is only carry out under fully grounding, the conclusion from its result may be untrustworthy.

Reference

[1] "Fault Management in Electrical Distribution Systems", *Final report of the CIRED Working Group WG03—Fault Management*

[2] H.Roman, paper 4.36 CIRED 1997 Conference Papers