Analysis of voltage sag source location based on wavelet-multiresolution method

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Abstract—The method of voltage sag source location proposed in this paper is using wavelet-multiresolution to decompose the voltage and current waveforms from monitoring points and analyzing the change of signal energy of three-phase instantaneous power during voltage sag to ascertain the sag source location relative to the monitoring points. The location of voltage sag caused by line fault, transformer energizing and induction motor starting, which are the main reason of sag, are analyzed and tested using this method based on a PSCAD simulation model in this paper. The results show that the method is simple and reliable and can be used to determine sag source location.

Keywords- Voltage sag; Location; Wavelet transform; Multiresolution analysis; Instantaneous power

I. INTRODUCTION

Voltage sag is a common power quality problem in power system, line fault, transformer energizing and induction motor starting, may cause sag. In recent years, power electronics equipment and microprocessor equipment are widely used in industrial production and they are particularly sensitive to sag. So when sag happens, it may lead to equipment damage and malfunction, which will cause great economic losses to customers.

For the electricity sector, if the loss of customers caused by sag increased, the economic disputes will also increased. So the analysis of voltage sag source location is necessary for fault detection and diagnosis of power quality, the distinction between economic responsibility, payment and the formulation of mitigation measures.

There are some studies on voltage sag source location at home and abroad[1-8]: It uses disturbance power and disturbance energy to determine the sag source relative to monitoring points in [1-3]; In [4], it judged the location from impedance and phase angle change before and after sag, which seen from the relay installed in lines. The limitations of this method lies in relay direction errors affected by location of faults and other factors; In [5] and [6], It determined the location according to positive and negative condition of the real and imaginary parts of equivalent impedance before and after sag. The difficulty is that the choice of measurement period before and after sag may affect the outcome’s correctness. The method of fitting a straight line to the data of |Ucosθ| and I during sag is used in [7], and the slope of line is the basis of location. But the accuracy is not satisfactory when judging asymmetric fault[8].

In view of that the method of energy analysis can directly use voltage and current waveforms in monitoring point to calculate, this paper studies from the energy flow in monitoring points during sag time. With different from integral method of disturbance power to calculate disturbance energy in [1-3], in this paper, it first calculated the three-phase instantaneous power changes during sag, then calculated energy change of power signal by method of wavelet multi-resolution analysis to determine the sag source location.

II. ANALYSIS OF ENERGY METHOD

A. analysis of the cause of sag

When line fault happening, transformer energizing and induction motor starting, it may caused voltage sag. When line fault appeared, current in short circuit greatly increased due to the decrease of power supply circuit impedance and sudden transient process, which will drop voltage in system; the need for current from power source is 500% ~ 800% compared to full load when induction motor starting, it will cause voltage drop when large current flowing through the system impedance[9]; When transformer energizing, it will generate the inrush current which is several times of rated current in transmission-side due to core saturation, and it also caused voltage sag[10].

By above analysis, the sag process can seen as that the sag source absorbed energy from system. When sag occurs, the energy flowed to the position of fault. So we can locate the sag source by instantaneous energy flow in network.

B. the location method

Generally speaking, power quality monitoring is the common needs both of electricity sector and customers, and the data of monitoring points can provide objective factual information to both side. Monitoring points is often the common connection point, such as the substation bus, connections points between systems and customers, etc. So the location of voltage sag can be judged relative to the monitoring points.

Specifically, as Figure.1 shown below, we can refer to the direction of fundamental active power to locate the sag source. If sag occurred in the rear of monitoring device, it is called the upstream direction; Instead, it is called the downstream direction. If the energy sag decreased compared to when it was in steady state of same time, the sag source is
in upstream direction of monitoring point; instead, in downstream direction.

\[ E \text{ is the signal energy during sag, } E_0 \text{ is the signal energy in steady state in the same time. } \Delta E=E-E_0, \ \Delta E \text{ is the change between E and } E_0. \text{ The criterion is: when E decreased in the initial time of sag and } \Delta E \text{ is negative during sag, the sag source is behind the monitoring point; instead, it is before monitoring point.} \]

IV. SIMULATION STUDIES

A. Simulation model

The following diagram shows the simulation system structure of voltage sag source location study, and M1-M5 are monitoring points. In this paper, the typical sag such as line fault, transformer energizing and induction motor starting are simulated using PSCAD, and voltage and current waveforms in each monitoring point are got.

B. The choice of wavelet function

The choice of wavelet basis function is the key to wavelet application. Considering the compact support in time and frequency domain is particularly important. db wavelets is consequently recommended in power system for the character of orthogonal, time-frequency compact support and high-normal[12]. db4 is adopt in this paper because it has the shortest time window and better time resolution than other wavelets.

Multi-resolution signal analysis and signal energy calculation is completed using Matlab in this paper.

C. line fault

1) The three-phase symmetrical fault is set in overhead line l of 110kV. The figure 3 is the energy change during sag in M5, and figure 4 shows the comparison between sag and steady state(Blue represents the steady-state while red represents sag, the same representation in the following figures).
From the calculated results and the above figure we can see that, the energy of each monitoring point in the beginning of sag and the period of sag both decreased. The fault is judged using the method in this paper behind all monitoring points, which also means it is in upstream direction. That is consistent with the simulation situation.

2) The three-phase symmetrical and asymmetric fault are set in overhead line l1 of 10kV. The figure 5 and 6 are the energy change during sag in M1. Under two cases, the energy both rise in the initial time. The table 1 shows the comparison of ΔE. According the data in table 1, in M1 and M5, energy increased, in other points the energy drop. So the sag source is judged before M1 and behind M2, which is same with simulation.

<table>
<thead>
<tr>
<th>ΔE</th>
<th>Symmetrical fault</th>
<th>Asymmetric fault</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1</td>
<td>145062</td>
<td>38598.73</td>
</tr>
<tr>
<td>M2</td>
<td>-73.619</td>
<td>-49.9341</td>
</tr>
<tr>
<td>M3</td>
<td>-80.5212</td>
<td>-39.9574</td>
</tr>
<tr>
<td>M4</td>
<td>-36.49</td>
<td>-28.0921</td>
</tr>
<tr>
<td>M5</td>
<td>15321</td>
<td>48998</td>
</tr>
</tbody>
</table>

D. transformer energizing

The transform T3 is put into operation. The figure 7 is the change of energy in M5, and figure 8 is the comparison of energy in each monitoring point. From the results, we can judge the sag source is before M5 and in the rear positions of M1 and M2, which is same with simulation.

E. induction motor starting.

The figure 9 and 10 shows the energy change of induction motor starting.
According that the energy in M3 and M5 rise during sag ,
the sag source is judged before them; according that
the energy in M1 and M4 decreased ,the sag source is after them.
So we judged that the sag source between M3 and M4, and it
is consistent with simulation.

V. CONCLUSION

In this paper, wavelet multi-resolution analysis method is
used in sag source location on basis of the voltage and current
waveforms got by the widespread voltage and current
detection device in monitoring points. The method is simple
and its’ correctness is test by simulation study.

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