A fault analysis for Micro-grid based on Wavelet

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Abstract. Micro grid is an efficient and flexible way to solve the problem of grid-connected distributed generation. Since the distributed generation accessed and the number of branch increases, system fault condition is complicated. Micro grid fault protection becomes a hot issue now. In this paper, a method based on wavelet is proposed for micro grid fault current analysis. A typical 10kV micro grid model is established in PSCAD, which is consisted of wind power, PV, EV and so on. And, short circuit fault is simulated. Then, the fault current data is further dealt by Harr wavelet. The results would provide a good guide for the setting of fault protection scheme.

1. Introduction

Micro grid is an efficient and flexible way to solve the problem of grid-connected distributed generation. It also could improve the reliability of power supply [1]. Since the distributed generation accessed, the power supply mode of the distribution network has changed from single power supply to Multiple power supply. As the number of branch increases, system fault condition becomes complicated [2]. When the short circuit fault occurs in the system, the short circuit current could be provided by more than two power sources, which makes the traditional fault analysis and calculation method of distribution network difficult to be applied in practice and affects the determination of the fixed value of its protection. The type, installation location and capacity of distributed power supply will affect the relay protection of distribution network [3]. Hence, micro grid fault protection becomes a hot issue now.

More attentions are paid to the processing of fault signal, because it is the prerequisite to relay protection of distribution network. To solve leakage and fence effect when using fast Fourier transform, an optimal detection algorithm based on combination wavelet threshold denoising and fast Fourier transform was proposed [4]. FFT method is used to analyze the spectrum of four signal models in power system. The result shows that FFT method could well identify harmonic components with fixed amplitude and inhibit the interference of Gaussian white noise in the system. However, FFT method could not accurately obtain the signal spectrum when the frequency is not fixed [5]. In order to improve the accuracy of parameter estimation of harmonics and inter-harmonics, a new double-window all-phase Fourier algorithm based on Blackman window is proposed. Compare with other FFT methods, the method proposed has higher accuracy of signal parameter estimation [6]. Quantitative analysis of phase error based on WFFT is done to improve the speed of harmonic measurement on the premise of known phase accuracy requirement [7]. Compared with FT, DFT
solves the problem of analyzing continuous function. While the speed of operation is too slow to meet the need of the microgrid which has a high requirement of operation speed [8]. A multi-agent system combining wavelet neural network Combination of fault diagnosis method is proposed. In this method, the wavelet SOM neural network is used to judge the cause of the fault and the fault location could be determined by using the multi-agent system[9]. The extended discrete Fourier transform (EDFT) algorithm is applied to the harmonic detection. The algorithm has high frequency resolution and strong anti-interference ability, and is suitable for the high precision measurement or detection [10]. Most of the traditional relay protection methods are digital filtering based on the Fourier transform. Due to Fourier transform does not have the characteristic of frequency localization, the method has some limitations in dealing with non-stationary fault signals [11-13]. In this paper, a typical microgrid model including PV generation and other distributed energy is established in PSCAD. And three phase short circuit is simulated and the fault signals are decomposed by Harar wavelet.

2. Typical Model of Microgrid
The components of the microgrid include different types of distributed energy, user terminals of various electrical and/or thermal loads, and related monitoring and protection devices [14]. Ac microgrid is still the mainstream in the current domestic and foreign microgrid. Ac microgrid does not change the original grid structure, and is suitable for the transformation of the original grid into a micro-grid grid structure [15]. Under normal circumstances, micro grid and large grid operate in parallel, when the main network fails, the static switch would be disconnected, and micro grid will operate independently of the system. When power grid gets back to normal, micro grid could be reconnected with the main network. The typical structure of microgrid is shown in Fig. 1.

![Figure 1. Structure diagram of microgrid.](image)

For example, a 10kV distribution network model with micro grid is established in Fig. 2. The components of the microgrid mentioned above include PV generation, wind generation, energy storage station and different AC loads [16]. The fault time is set at the moment of 0.3 seconds, and the fault lasts for 0.2 seconds. $I_1$ represents the current of the fault line and $I_2$ represents the current of the adjacent line. The impact of the fault could be judged through the comparison of the two.
3. Microgrid Fault Model and Wavelet Analysis of Fault Signal

3.1. PQ Control Fault Model for Microgrid

Distributed energy sources such as PV and energy storage are called inverter interfaced distributed generation (IIDG) [17]. IIDG is often controlled by PQ method at a given reference power. PQ control diagram of IIDG inverter is shown in Fig. 3. At this point, IIDG is equivalent to a constant current source.

The equivalent circuit of IIDG is shown as Fig. 4. Among them, \( E \) represents output voltage of IIDG; \( U_s \) is the grid voltage; L and R represent filter inductance and resistance respectively.
According to instantaneous power theory, the actual output power of DG can be expressed as (1) in the synchronous rotation dq coordinate system [12]:

\[
\begin{align*}
P_{\text{out}} &= \frac{3}{2} \left( U_d I_d + U_q I_q \right) \\
Q_{\text{out}} &= \frac{3}{2} \left( U_q I_d - U_d I_q \right)
\end{align*}
\]  

Among them, \( P_{\text{out}} \) and \( Q_{\text{out}} \) represent the active power and reactive power of the DG output respectively; \( U_d \) and \( U_q \) represent the d-axis and q-axis components of the voltage of PCC; \( I_d \) and \( I_q \) are the d-axis and q-axis components of the voltage of PCC respectively. If the d axis is oriented to the voltage of PCC, then we could get \( U_d = U_{\text{max}} \) and \( U_q = 0 \). DG output power could be simplified to (2):

\[
\begin{align*}
P_{\text{out}} &= \frac{3}{2} U_d I_d \\
Q_{\text{out}} &= \frac{3}{2} U_d I_q
\end{align*}
\]

In case of failure, the AC side of the DG only outputs positive sequence current. The DG could be equivalent to a positive sequence current source model controlled by positive sequence voltage of parallel node, which can be expressed as (3):

\[ I_{\text{pgf}} = f(U_d^+) \]  

Considering that DG does not output additional reactive power during low voltage crossing, then \( I_q = 0 \). The fault current of DG output is:

\[
\begin{align*}
I_{\text{qf}} &= 0 \\
I_{\text{df}} &= \min \left\{ \frac{2P_{\text{ref}}}{3U_{\text{ref}}^+} I_{\text{max}}, I_{\text{ref}} \right\} \\
I_{\text{magf}} &= \sqrt{I_{\text{df}}^2 + I_{\text{qf}}^2}
\end{align*}
\]

Among them, \( I_{\text{qf}} \) and \( I_{\text{df}} \) are respectively the reactive power current of DG output in case of failure; \( I_{\text{df}} \) is the d-axis component of the positive-sequence voltage vector directed at DG; \( U_{\text{ref}}^+ \) is the voltage positive sequence component of the ac side of the DG in case of failure; \( I_{\text{max}} \) is the maximum fault current of DG output, which generally could not exceed 2 times of rated current; \( P_{\text{ref}} \) is the active reference power; \( I_{\text{magf}} \) represents the magnitude of the fault current.

### 3.2. Haar Wavelet Analysis for Fault Signal

Haar Wavelet Transform was proposed by Alfred Haar in 1909. The concept of Harr wavelet transform is similar to that of Fourier Transform. The principle of Fourier Transform is to use chord sine and cosine to modulate signals, while Haar Transform uses Haar function to modulate signals. Mother Wavelet of Harr Wavelet is described by (5).

\[
\psi(t) = \begin{cases} 
1 & 0 \leq t < 1/2 \\
-1 & 1/2 \leq t < 1 \\
0 & \text{otherwise}
\end{cases}
\]  

The corresponding scaling function could be expressed by (6).

\[
\phi(t) = \begin{cases} 
1 & 0 \leq t < 1 \\
0 & \text{otherwise}
\end{cases}
\]  

The filter h[n] is defined by (7).
The flow chart of Haar Wavelet of fault current is shown as Fig. 5.

![Flow Chart](image)

**Figure 5.** The flow chart of Haar wavelet of fault current.

4. Simulations

4.1. Three-Phase Grounding Short Circuit Simulation

The simulation model is established in PSCAD/EMTDC. The total simulation time is 1 second, ABC three-phase grounding short circuit occurred at 0.3s and last for 0.2s. The current waveform of fault line and the current waveform of adjacent line are shown in Fig. 6 and Fig. 7.

![Current Waveform](image)

**Figure 6.** The current waveform of fault line

**Figure 7.** The current waveform of non-fault line

4.2. Haar Wavelet Analysis of Fault Current

After wavelet analysis, the result are shown in Fig. 8 and Fig. 9.
It could be seen in Fig. 8 and Fig. 9, that the transient characteristic is extracted by wavelet transform. The result could be used to deduce the fault line and the time of fault occurrence. Reasonable setting calculation could ensure the selectivity of relay protection to the fault of the feeder where the micro grid is located. Protection could be configured according to the result obtained by wavelet analysis.

5. Conclusion

Microgrid has the advantage of efficiently using different kinds of distributed energy, and could be used as an effective complementary grid of the main grid to improve the reliability of power supply. When Micro grid is grid-connected, the structure of the traditional power supply will be changed, and the condition of relay protection in distributed network becomes complicated. Several factors, such as, the type, installation location and capacity of distributed power supply will affect the relay protection of distribution network. More attention need to be paid to the processing of fault signal, because it is the basis to set a relay protection scheme for distribution network. In this paper, a typical 10kV micro grid model is established in PSCAD/EMTDC, which is consisted of wind power, PV, EV and other loads. A three-phase grounding short fault is simulated. And for a further processing, Harr wavelet is used to deal with the fault current data. The analysis results could provide a good support for fault protection setting.

6. References

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